GLAST Large Area Telescope:

AntiCoincidence Detector (ACD) Critical Design Review (CDR)

Mechanical Subsystem

ACD Mechanical Team

NASA/Goddard Space Flight Center
January 7 & 8, 2003

ACD Mechanical Team Members

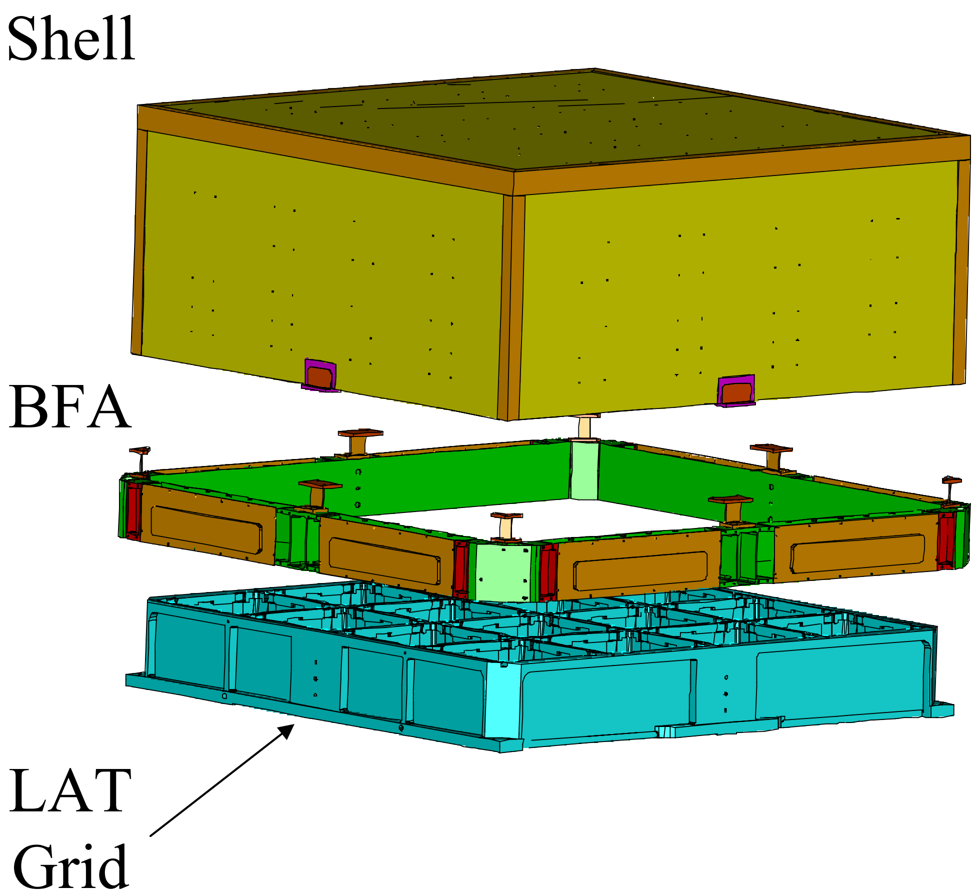
- **Recognizing the ACD Mechanical Team members for all their hard work and often long hours (and long meetings)! :**
  - *Cengiz Kunt, Sheila Wall, Kevin Dahya, Ben Rodini, Diane Stanley, Bryan Grammer, Ian Walker, Bob Reely, Russ Rowles, Wes Alexander, Matt Showalter, Ray Suzidellis, Monique Fetzer, Jim Woods, David Dollard, Frank Rondeau, Pilar Martin, Marva Johnson, Jonathan Kunz, Scott Gordon, Steve Chaykovsky*

- ***Materials Branch Personnel* for their coupon test support.**
- ***Environmental Test Branch Personnel* for their structural test support**

ACD Mechanical Subsystem CDR - Outline

- ACD Mechanical Subsystem Review
  - Overview – Ken Segal
  - ACD Mechanical Design
    - TSA Design - Ben Rodini
    - TDA Design– Ken
    - BFA/BEA Design – Ken
  - ACD Mechanical Analyses
    - TSA Analyses– Sheila Wall
    - TDA Analyses– Cengiz Kunt
    - BFA/BEA Analyses – Kevin Dahya
  - Thermal Design/Analyses – Carlton Peters
  - ACD Manufacturing – Russ Rowles
  - Summary – Ken

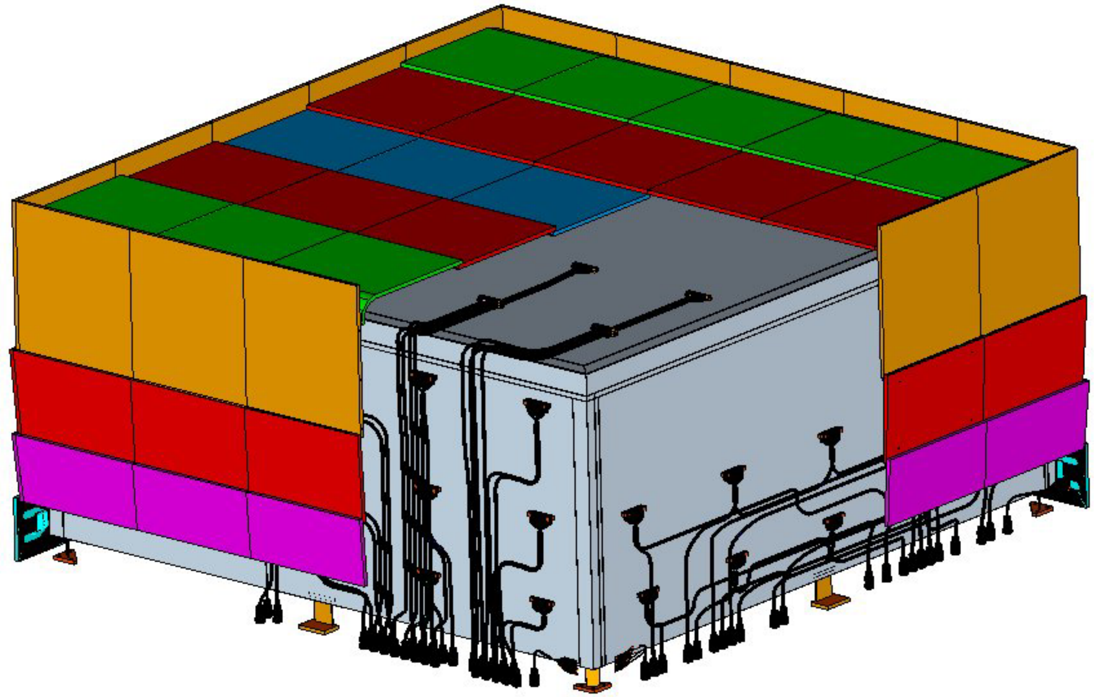
ACD Overview



- **89 Tile Detectors**
- Tiles are mounted on a Tile support structure
- TSA is mounted to a Base Frame Assembly (BFA) support structure
  - BFA holds ACD Electronics (to become the Base Electronics Assembly (BEA))
  - Mechanical and Electrical I/F to LAT

ACD Mechanical System Overview

Tile Shell Assembly (TSA)



Composed of

- 89 Tiles Detector Assemblies (TDA)
    - Optically Transmissive Cables
    - 8 Ribbon Detectors
- Shell Assembly
    - Composite Honeycomb Panels
    - 368 Composite *Tile* Flexures
- 8 *Shell* Flexures

ACD Mechanical System Overview

BASE FRAME ASSEMBLY (BFA)

•Main Structural Element of the Base Electronics Assembly (BEA)

COMPOSED OF

• 4 Identical Machined Aluminum Parts bolted together

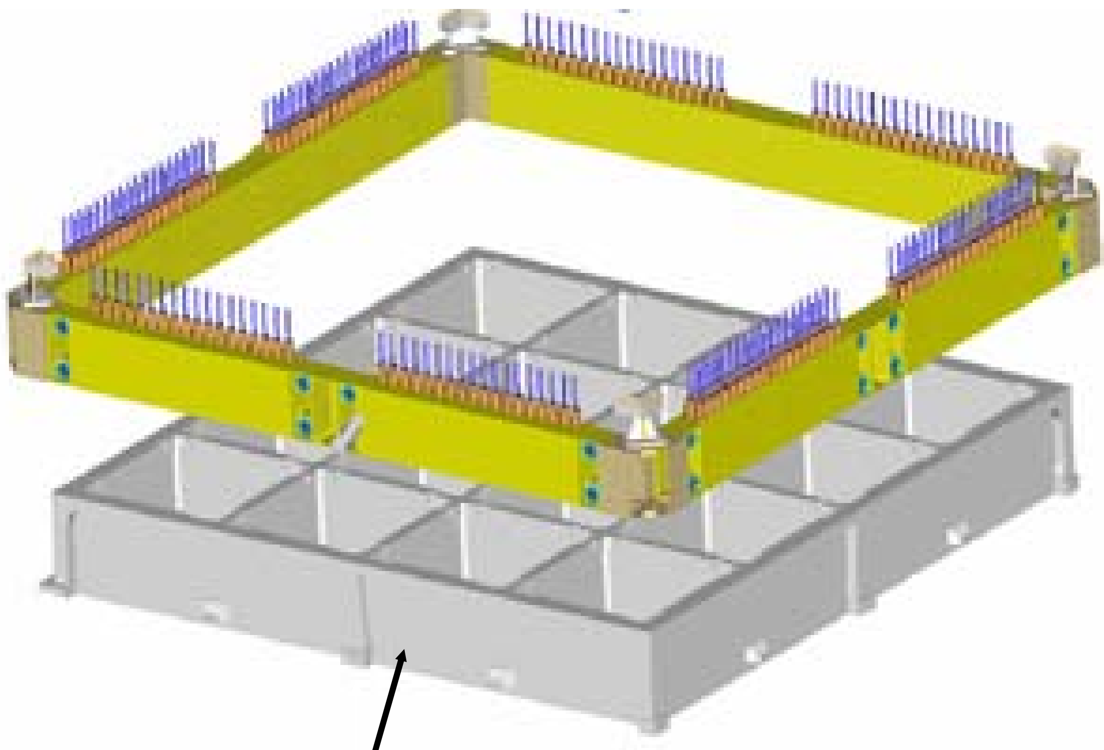
•Electrical Chassis Closeout covers

PROVISIONS FOR

•8 Electronics Chassis Assys

  •Easy Removal

•ACD-LAT Structural Interfaces



LAT Grid – Mechanical/Thermal Interface to LAT

ACD Mechanical System Overview- Engineering Challenges

- Mount High Differential CTE Materials Together.
  - High CTE Plastic Tile to Low CTE Composite Shell
  - Low CTE Composite Shell to High CTE Aluminum Base
- Packaging
  - Detectors
    - 89 Tiles
      - Minimal Gaps
      - 65 Clear Fiber Cables
    - 8 Ribbon Detectors
  - Electronics
    - Provide Volume for 194 PMT's and Associated Circuitry in 8 Electronic Bays.
    - Provide Easy Access (for I&T)
    - Design to Minimize Spare Parts

ACD Mechanical System Overview-Requirements

Document Title	Document #	Status
ACD-LAT Interface Control Document-Mechanical, Thermal and Electrical	**LAT-SS-00363-043**	**•Signed off**
ACD-LAT Mechanical Interface Definition Drawing	**LAT-DS-00309**	**•In Sign off**
LAT ACD Subsystem Specification-Level III Spec	**LAT-SS-00016-R3**	**•Signed off**
ACD Verification Plan	**ACD-PLAN-000050**	**•Signed off**
ACD Subsystem Spec-Level IV Requirements	**LAT-SS-00352**	**•Signed off**
LAT Environmental Limits	**LAT-SS-00788**	**•Draft**
Structural Design and Test Loads for the GLAST ACD	**ACD-SPEC-006**	**•Internal ACD Mech Team Document- April 2001 version**

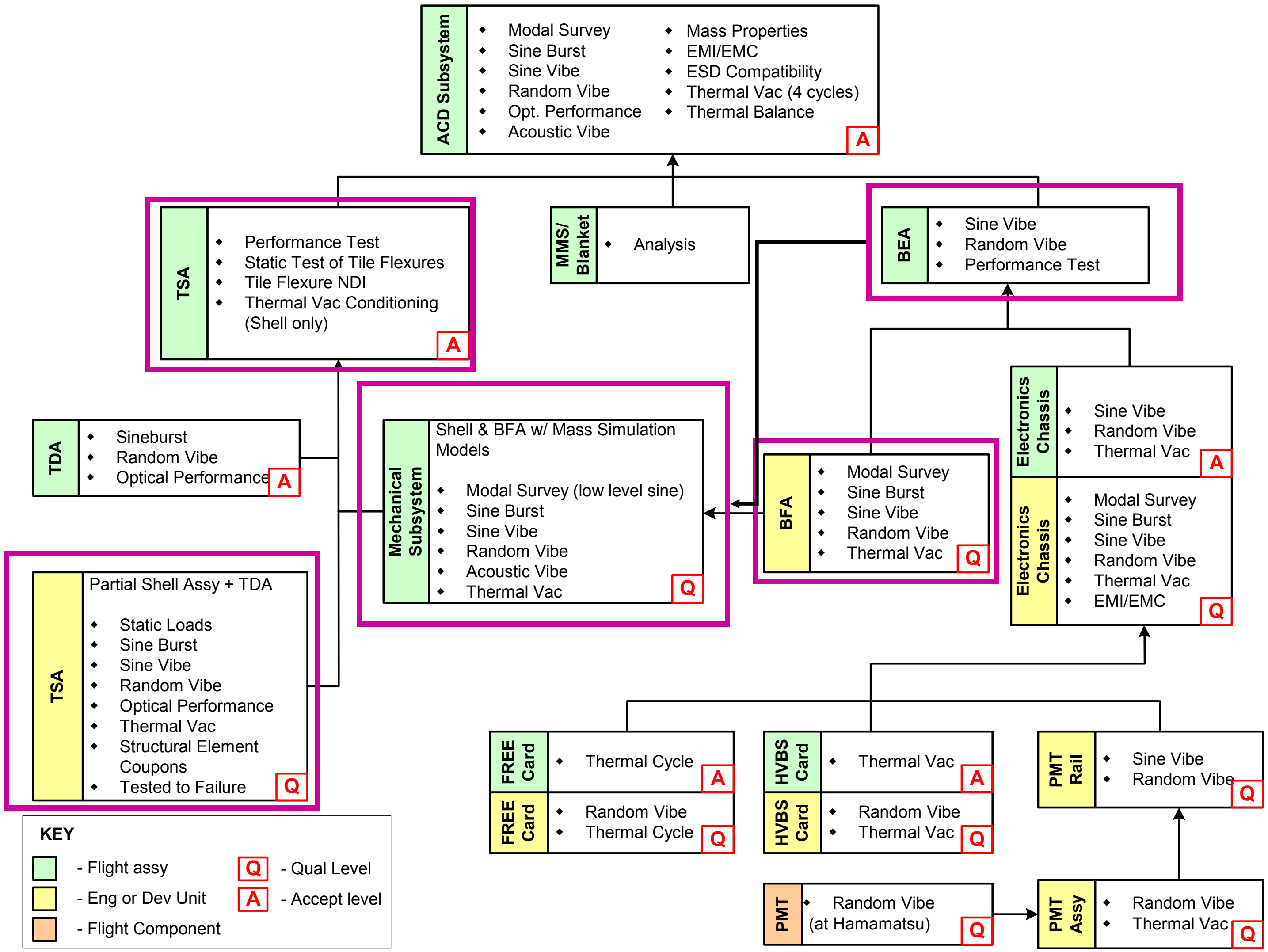
Compliance Matrix

Requirement	Compliance	Comments
•Physical Interfaces –Per IDD	Yes *	•IDD is in sign off * ACD designs conform to ‘agreed to’ interfaces.
•Volume –Per IDD	Yes *	•IDD is in Sign off * ACD dimensions conform ‘to agreed’ volume.
•Mass <280kg	Yes	•Current ACD Mass estimate = 270Kg.
•Attenuation < 6%	Yes	Calculations show attenuation @ 5.6%.
•Interface Loads –Per ICD	Yes	•ICD Loads Tables in latest revision –ICD Revisions completed, ICD signed off
ACD shall be Removable	Yes	•Non-interference fit pin connection to LAT Grid

Compliance Matrix

Requirement	Compliance	Comments
•CG X & Y : 0 $\underline{+}$ 5mm Z < 393	Yes	•Verification though analyses and tests.
Venting	Yes	Venting through one side of all panels away from Trackers
Environmental Loads	Yes	Proved through analyses and tests.
5 year life	Yes	Analyses
>50Hz Fundamental Frequency	Yes	Current ACD first mode = 56Hz.
Contamination –Level 750B, MIL-STD-1246	Yes	•All Materials approved for flight •Structural cleanliness is addressed with coatings, solvent wipes and process controls. • Composite Structure will see a thermal vacuum bake out.

ACD Mechanical Structures Verification



Changes Since PDR

- Mass Allocation Increased to 280Kg
- Tile Size Increases
- Clear Fiber Cables Termination Points Moved

PDR AI Status:

AI Number	Action
1.	Finalize TDA bottom row design - *Complete*
3.	Fiber routing mock-up - Complete

Mechanical Peer Review - AI Status

- ACD Mechanical Peer Review Held on Dec 6, 2002:
  - 20 Actions Assigned to ACD Team
    - All Actions Assigned to ACD Team members.
    - 15 Actions Completed (not ‘closed’)
    - All Actions to be closed upon Peer Review Team approval.

ACD Peer Review Action Item-Status

Action Item Number	Action	Status	Comments
1	Quantify the system impacts from increasing the gap between the bottom tiles to allow traditional flexures.		
1A	Consider fixing tile at mid-span to reduce range for	open	Last option to be considered. This option
1B	If decision is to stay with existing design, provide design details of stick/slip flexures.	closed	**Design is complete.** Providing better design illustrations
1C	Provide verification plan and perform required testing.	open	**Test Plan Developed.** Perform testing
1D	Perform tile analysis with stick/slip joint loads.	closed	Tile stresses low.
2	Subject flight Honeycomb Panels to thermal cycling prior to delivery to GSFC with NDE performed pre- and post-thermal cycling.	closed	**Already planned -** Added to manufacturing flow chart.
3	Demonstrate concept for nut plate removal. Suggestion for a thin graphite piece to support the fastener as provided by sketch from reviewer.	open	**Test Plan Developed.** Perform testing to close this action.
4	Determine if the 50 Hz frequency a goal or a requirement. Should a goal drive the design and contribute to mass growth? If a requirement, is it in conflict with the overall 50 Hz requirement for the	closed	Requriement drafted in LAT ICD. ICD in signature cycle.
5	Consider lower honeycomb core density to reduce system mass and help attenuation requirement.	closed	Mass CR has been approved, Attenuation is below requirement. No need to reduce mass.
6	Reassess mass allocations and appropriate contingency levels before submitting change request to SLAC.	closed	Mass CR submitted asking for 27Kg contingency. 10Kg contingency approved, w/ Lat Holding 198 at the Instrument level.
7	Check negative margins on the BFA, are load cases too conservative?	closed	All Margins are positive for 304Kg Mass. Related to Action 15. Random vibration requirements reduced.
8	Add venting feature to blanket standoffs.	closed	Standoffs Vented
9	Consider incorporating latest ACD FEM into current Coupled Loads Analysis cycle.	closed	3 Week delay would result. Deemed unacceptable delay by LAT.
10	Consider postponing the CDR because of the many open issues to be resolved prior to the CDR.	closed	Postponement Considered. More Benefits than negative impacts expected with CDR to be held on Jan 7-8th

ACD Peer Review Action Items-Status

11	Address mounting the 2nd and 3rd row tiles which are mounted with compound angles and flexures are aligned radially.	open	Current Design shown workable. Addressing trade between machining tiles with angled holes and designing, testing and verification of angled flexures
12	Address ribbon attachment near steps in the top tiles and also the ribbon crossings.	closed	Ribbon attachment designs completed. Shown in CDR package.
13	Review the adequacy of the Velcro only blanket attachment to the ULTEM stand-offs. Verify strength of the attachment and consider adding a positive mechanical attachment.	closed	Velcor will be used with doublesided tape as required. Heritage will be used instead of analyses to show this appoach is acceptable
14	Reexamine the negative margins in the lift case. Rather than changing the flight design, assess changes in the lifting method and GSE design.	closed	Related to AI #7. Margins are positive for 304Kg mass. Traded additional .5Kg with additional design and analyses to make additional MGSE for lift case.
15	Reassess applying 10g unidirectional load from vibro-acoustics quasi-statically to the entire structure.	closed	Attained Vibroacoustic load relief from LAT. Loads reduced to 7gs. Positive Margins demonstrated.
16	Consider adding Belleville washers to optical fiber connectors to help maintain preload (and optical coupling) over thermal environment.	closed	Bellville washers incorporated.
17	Consider turning down the #4 fasteners used to attach the scintillator tiles to minimize, if not eliminate, tile damage from bolt threads bearing on the tiles.	open	Considered request. Opted to investigate fasteners with shoulders as first option. Turning fasteners will mean more potential movement of tile.
18	Consider reducing qualification temperature limits to no more than 10 deg C beyond predicted operational limits.	open	Temp limits modified. New temp requirements documented in LAT ICD. ICD needs to be signed.
19	Clarify the analysis inputs used to determine the "attenuation" budget of 6.13% which exceeds the requirement maximum of 6%. Show breakdown of	closed	New table generated and show attenuateion is at 5.6%. Table needs to be reviewed.
20	Assess optical fiber loads due to flexure loads pulling on them when tiles contract at cold survival temperatures.	closed	Tile moves a maximum of 1.0 mm under thermal loads. Strain relief of the optical fibers via optical connector mount designed in. Cables will not see loads.

ACD Mechanical Structure Top Level Schedule

- **Key Milestones**
  - 12/02 : Mechanical Structures Peer Review
  - 1/7-8/03 : ACD CDR
  - 7/25/03 : Complete TSA and BFA Flight Fabrication
  - 8/22/03 : Start ACD Mechanical Structure Verification
  - 10/13/03 : Deliver Qualified ACD Mech Structure to ACD I&T
  - 8/17/04 : Ship ACD to SLAC

- **Mechanical Team Deliverables:**
  - ACD FEM Model to GLAST Project
  - Verified Mechanical Structure to ACD I&T
  - Lift Fitting for ACD Lifts at SLAC

ACD Structural Subsystem Mass

Item	Estimated Mass (Kg)	Calculated Mass (Kg)	Actual Mass (Kg)	Total Mass without Margin (Kg)
Mechanical Hardware				
Shell Assembly		29.8004		29.8004
Shell/Base Middle & Corner Flexures	1.6000	5.9824		7.5824
Base Frame Assembly (BFA)		25.1535	0.1248	25.2783
Tile Flexures	4.3900		5.0320	9.4220
Clear Fiber Cable & Fiber Ribbon Tiedowns	1.1840	0.1984	1.6800	3.0624
Shield/Blanket Attachments	0.4000		2.5840	2.9840
ACD/LAT Interface Hardware			0.6000	0.6000
Uralane & Safety Cable	1.0000			1.0000
	Mechanical Hardware Total			79.7295

Mechanical Structure :

80 Kg of

270Kg Total ACD Mass

ACD Mechanical Structures- Design Status

- TSA
  - 95% Complete
- BFA
  - 98% Complete
- MGSE
  - 25% Complete

- Drawings
  - 20% Complete
- Procedures
  - 85% Complete

GLAST Large Area Telescope:

AntiCoincidence Detector (ACD)

Critical Design Review (CDR)

TSA Mechanical Design

Ben Rodini/Swales
Composites Structures & Materials
301-902-4262

NASA/Goddard Space Flight Center
January 7 & 8, 2003

Outline

- Overall Description
- Shell Design
- Tile Flexure Design
- Remaining Work

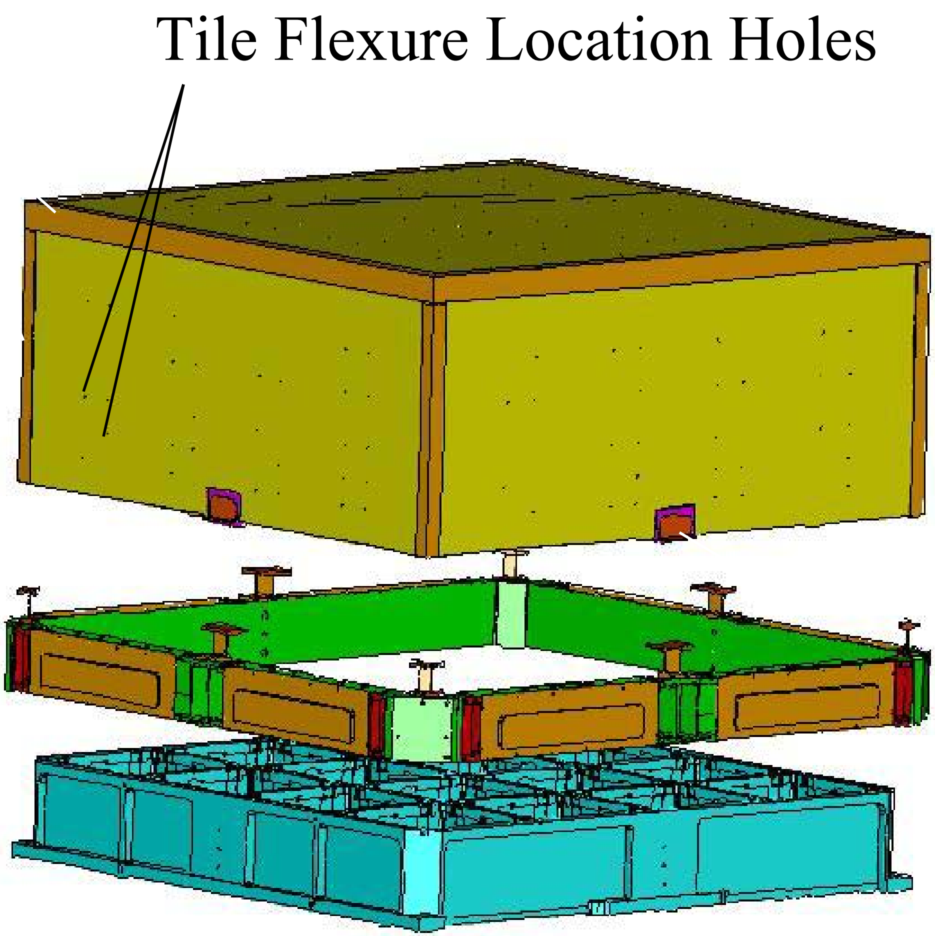
Shell Design Drivers

- Adequate Real Estate & Suitable Configuration to Mount TDA
- Sufficient Stiffness & Strength to Limit Vibro-Acoustic Loading and Deflection of TDA Elements
- Isolation of Thermal/Mechanical Loads and Deflections from the BEA
- Radiation Attenuation less than 6%
- Ascent Venting

Shell Design Requirements

- No Failure due to Launch & Thermal Loads
- Minimum Frequency: 50 Hz
- Shell Mass: 30.52 kg (Calculated)
- Overall Mass: 280Kg
- Attachment to Aluminum BEA
  - 4 Flexure Inserts @ Panel Mid-Spans
  - 4 Flexure Corner Inserts
- Temperatures
  - -18C to 31C Operation (Predicted)
  - -40C to +45C Qualification

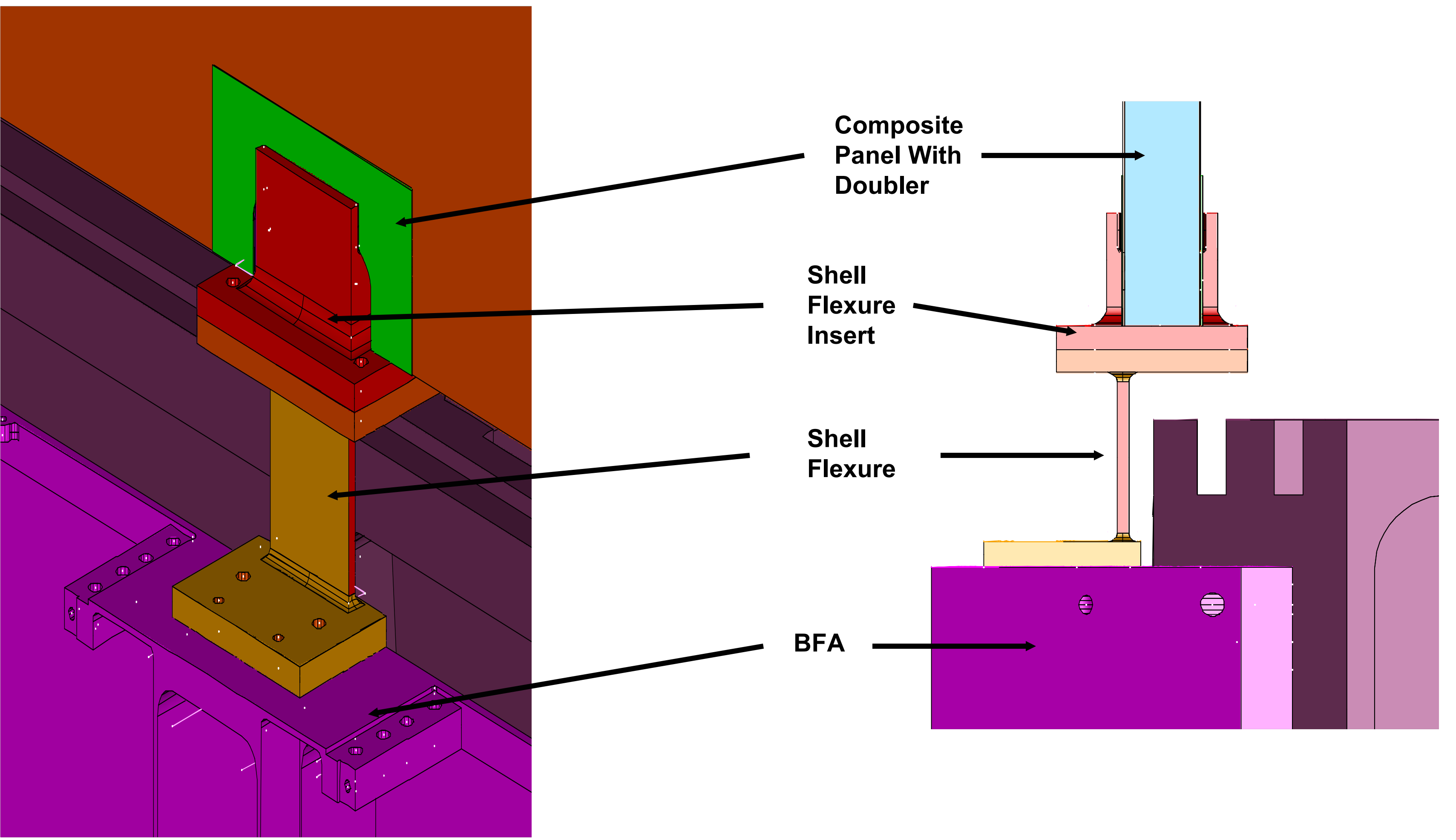
Shell



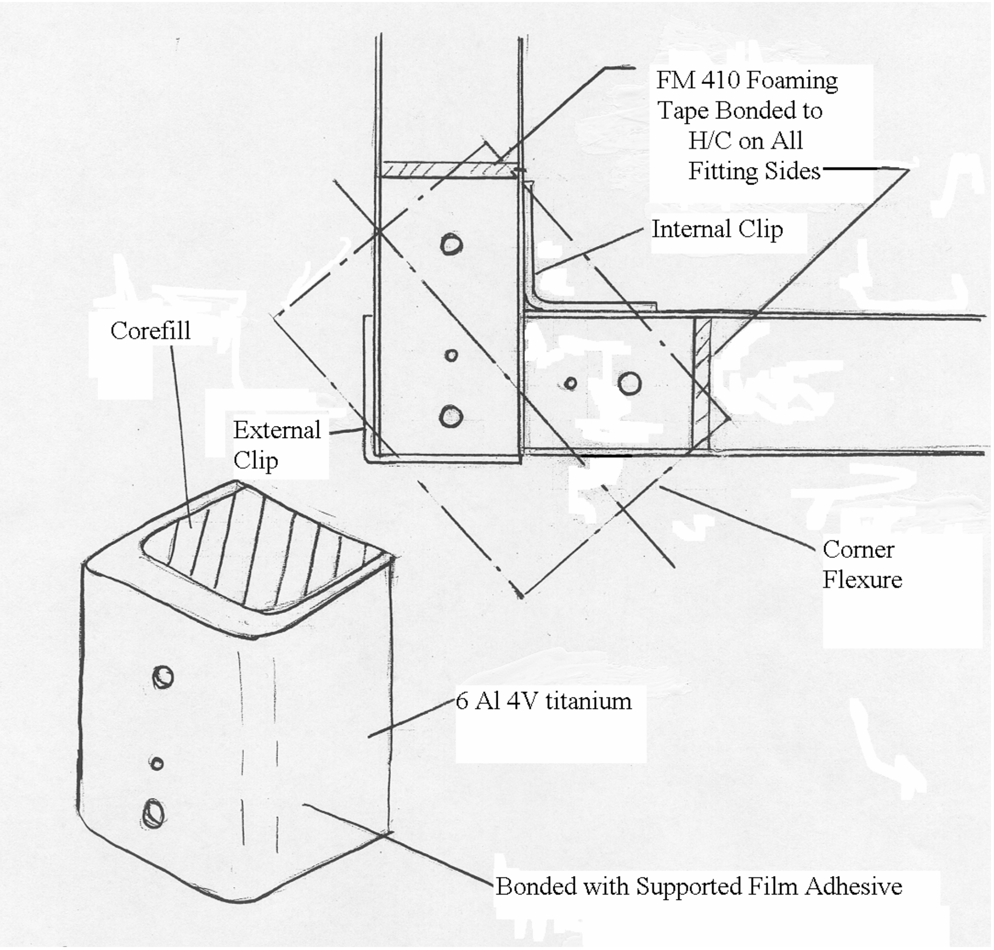
Construction / Materials

- Top & Side Panels
  - Facesheets: 20- mil M46J/EX1522, $[0/45/90/-45]_S$
  - H/C Core 3.1 PCF, 5056, 1”-Thick Sides, 2”-Thick Top
  - Film Adhesive: FM 73M, 0.045 PSF
  - Core fill: EY3010, Syntactic Epoxy
- Panel-to-Panel Joints
  - Mortise & Tenon (Tab & Slot) Features on Mating Edges of Panels
  - 20-mil Internal & External Clips: Braided Tape Wetted with EA9396
  - Edge Bonds: EA 9394 Adhesive
- Flexure Inserts
  - Mid-Span: 7075 External Channel/Block Post Bonded with EA9309
  - Corner: 6 Al-4V titanium Internal Insert Co-Cured with FM73M

Mid-Span Flexure Insert



Corner Flexure Insert

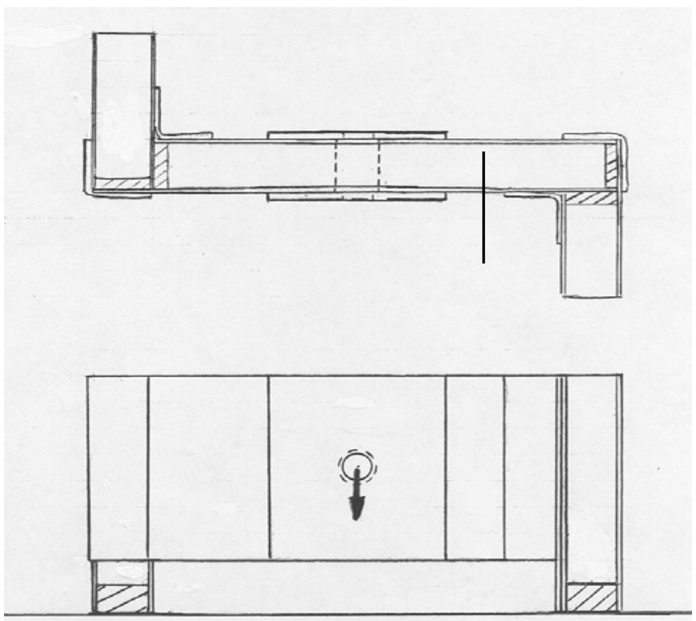


Shell Verification Tests

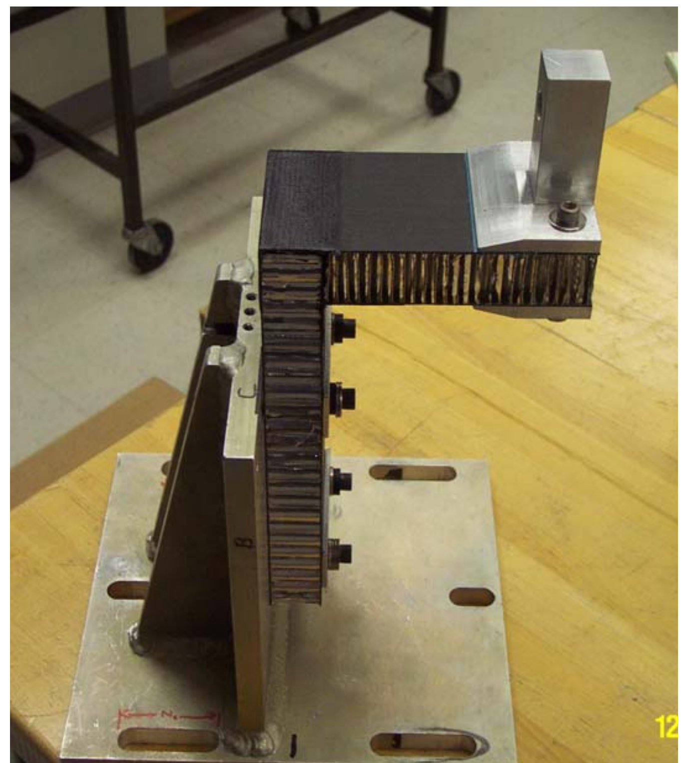
- Building Block Approach
- Laminate Characterization
  - See Test Matrix
- Sandwich Tests
  - Flatwise Tension
  - 4 Point Flexure
- Joints (Thermally Cycled and Un-cycled)
  - Panel-to-Panel
    - Bending
    - Sidewise Shear
  - Flexure Attachments (Thermally Cycled and Un-cycled)
    - Mid-Span (Tension, Shear 1, Shear 2)
    - Corner (Tension, Shear 1, Shear 2)

Panel Joint Specimens

Sidewise Shear

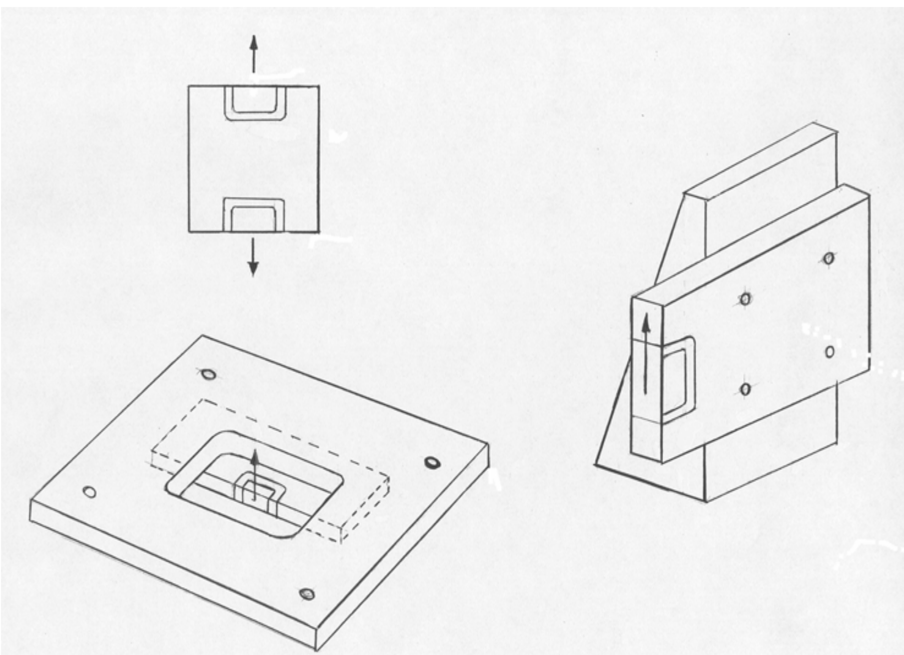


Bending

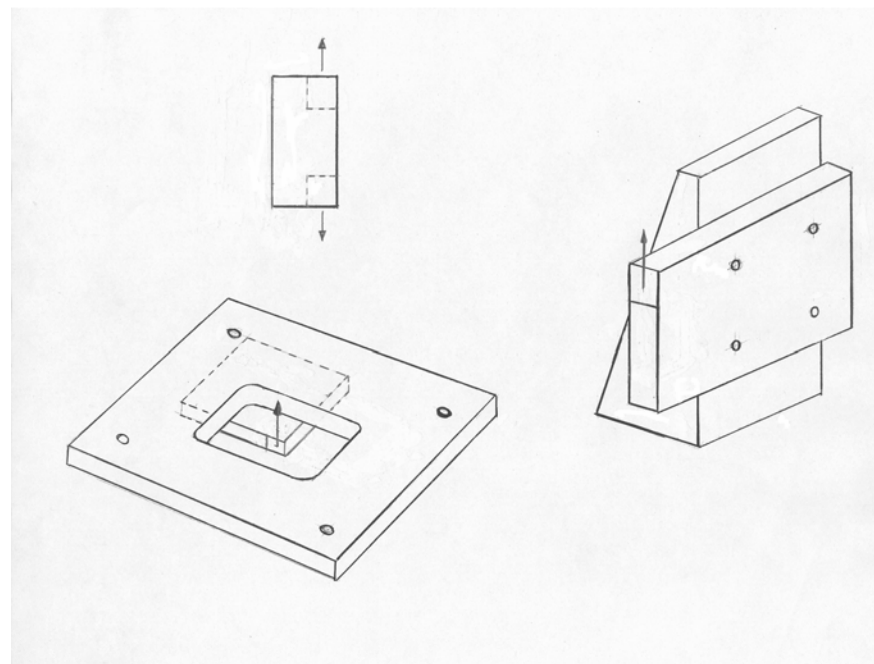


Flexure Insert Tests

Mid-Span Insert



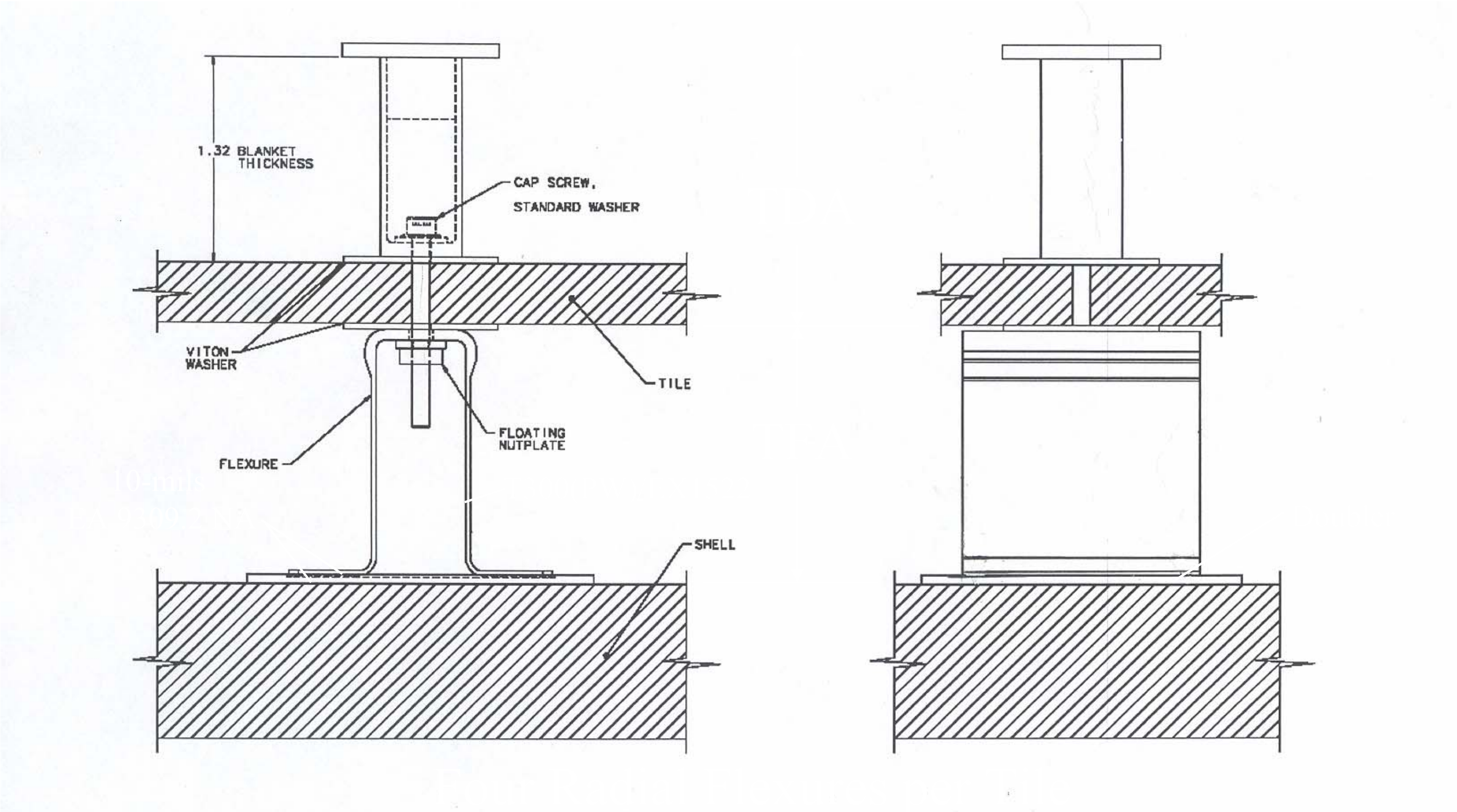
Corner Insert



Tile Flexure Design Drivers

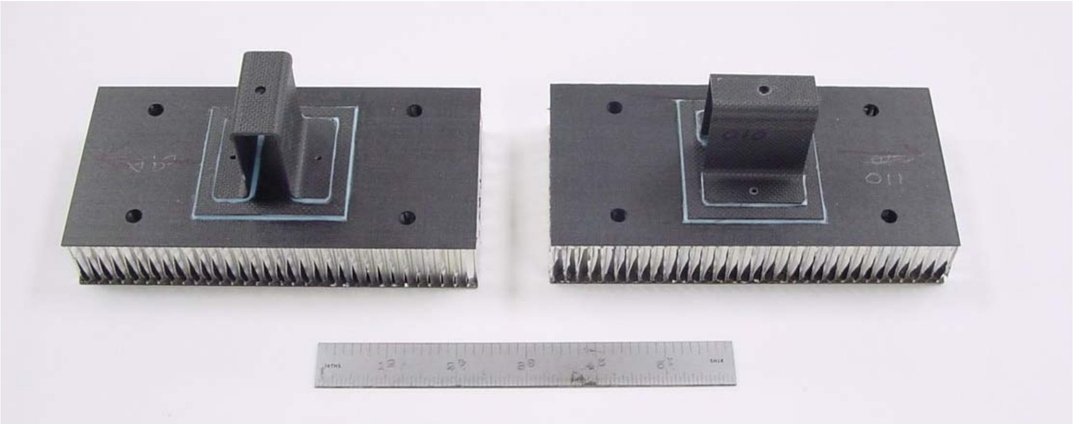
- Low Gamma-Ray Attenuation Material
- Adequate Deformation Capability to Accommodate Tile Thermal Shrinkage, In Plane
- Satisfactory Strength to Survive Vibro-Acoustic Loads
- High Vibratory Stiffness to Avoid Coupling with Shell
- Durability under Sustained & Cyclic Thermo/Mechanical Loads

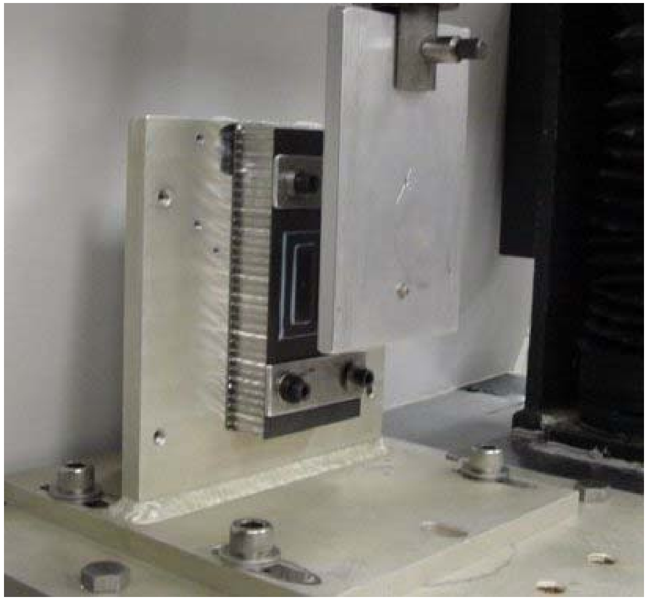
Tile Flexure Assembly



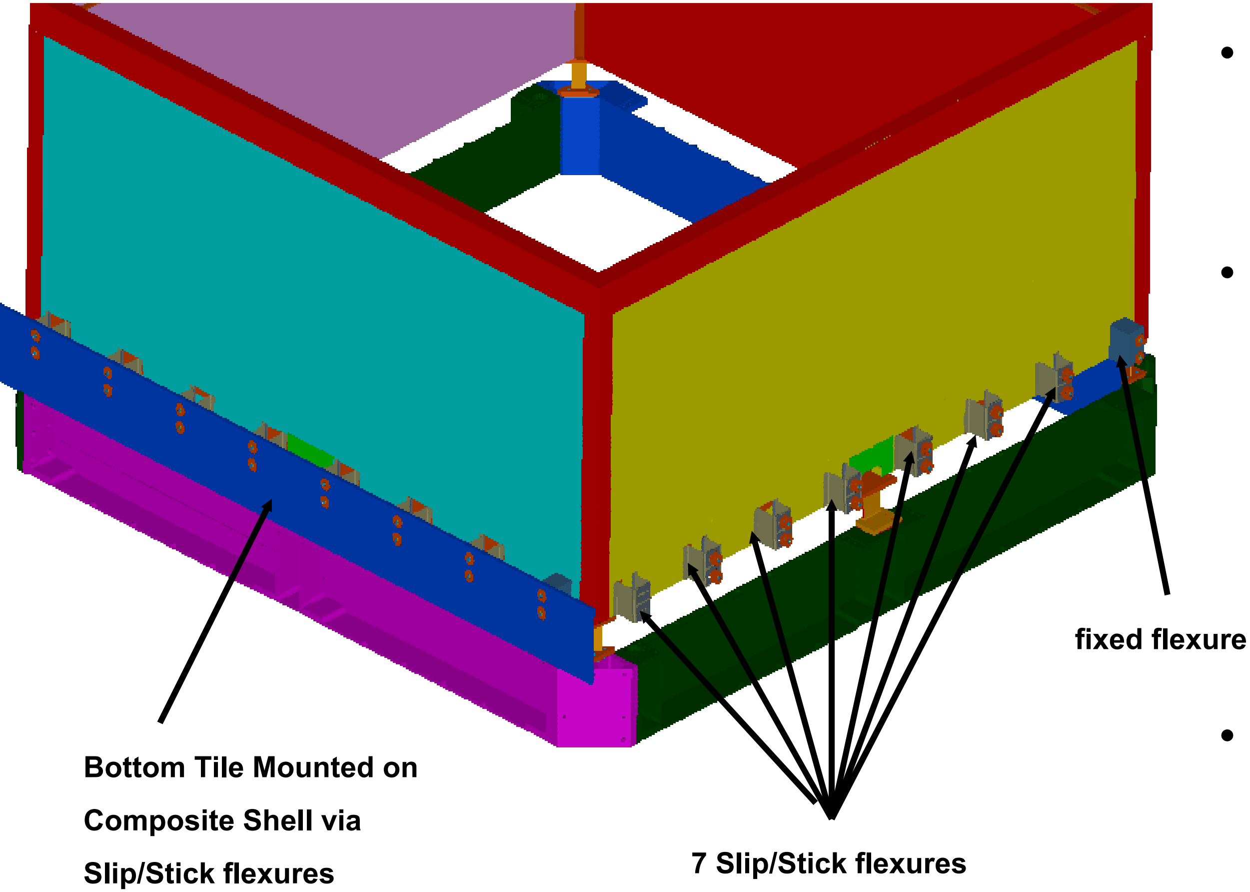
Flexure Characterization

- Material Acceptance Tests
- Doubler Laminate Mechanical Tests
- Flexure Laminate Mechanical Tests
- Flexure Consolidation
  - Photomicrographs
  - Web Mini-Beam-Specimens
  - Fiber Volume/Void Content
- Flexure/Interface Strength
  - Tension
  - Compression
  - Weak-Axis Shear
  - Strong-Axis Shear





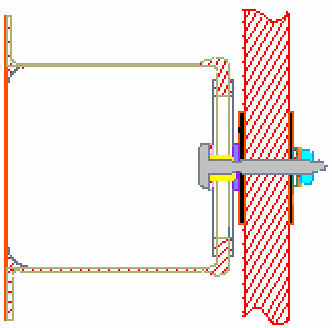
Bottom Tile Mount Design

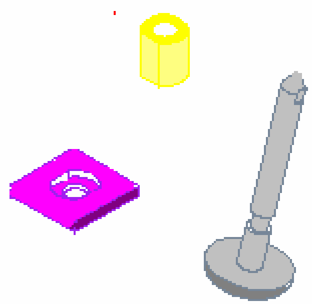


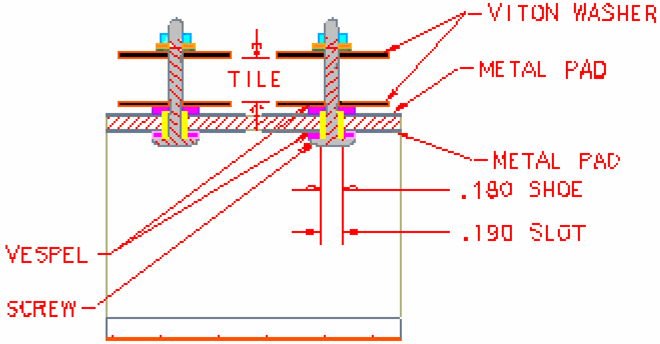
- Must Accommodate 8.4mm of Tile Thermal Expansion and Resulting Force
- Baseline Flexure Concept
  - 7 Flexures with Slip/Stick Features
  - One ULTEM “Post” for Displacement Restraint
  - Concept detailed in Next Chart
- Back-up Flexure Concept
  - 7 “Flexible” Flexures & One Post
  - Thinner Laminate & Taller than Tile Flexure

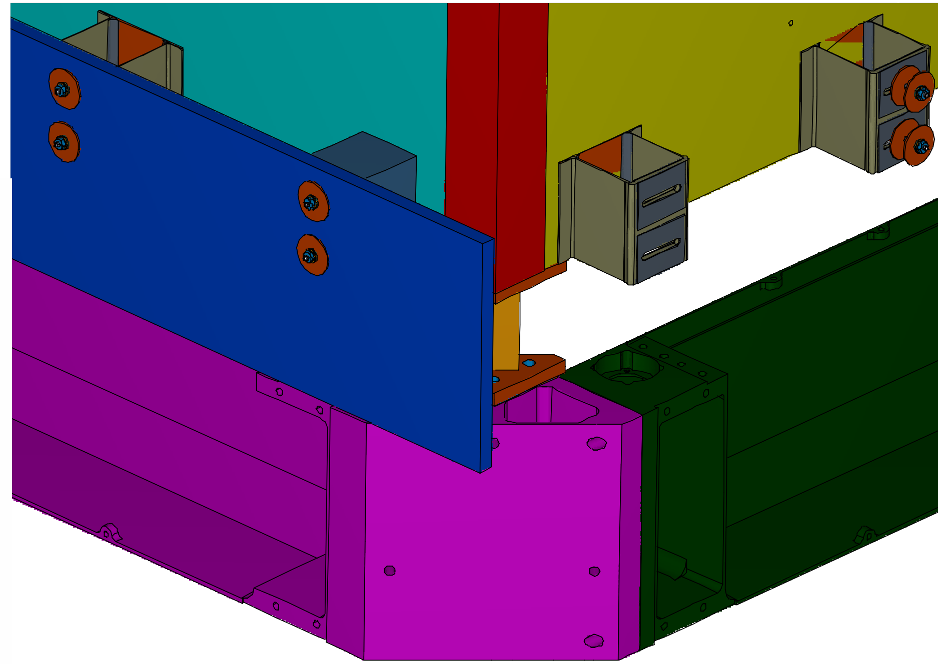
Bottom Tile Mount Design

Bottom Tile
Slip-Stick Composite Flexure







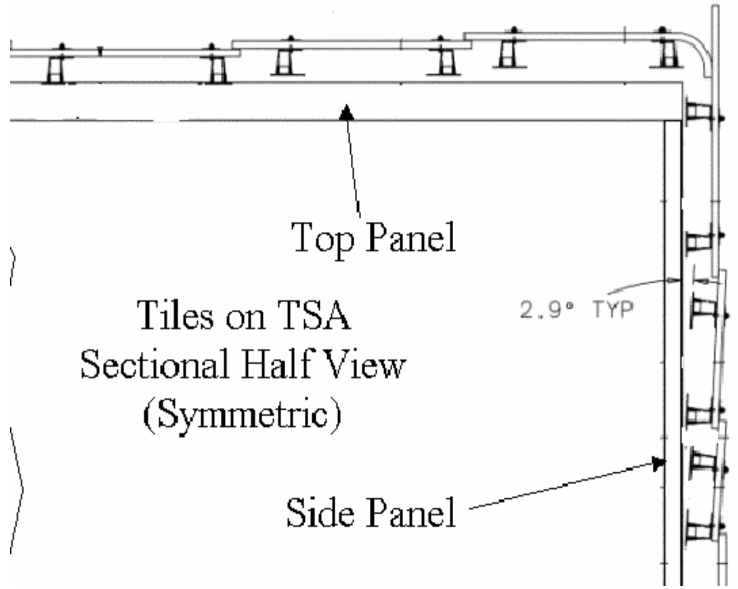


Bottom Tile Mount Qualification Testing

- Coupons for Rigid Support and Flexure bond testing. Compare analytical loads to test coupons results for margin of safety.
- Preload controlled with Belleville washer design and verified with button tile engineering unit testing.
- Bottom Tile Engineering unit - room temperature:
  - 4 slip-stick flexures for empirical determination of Belleville washer design and breakaway force vs. flexure preload (push-pull test)
  - Thermal effect simulation
    - Hot case - Increased preload due to tile growth (thickness) simulated by increased assembly torque
    - Cold case - Lowered preload due to tile contraction (thickness) simulated by reduced assembly torque.

Angled Tiles and Tile Gaps

- Shingled Tiles present Tile Gap Issues
  - Flexures will be Shimmed to Control Tile Gaps
- 2 Tile Rows (40 tiles) are Angled
  - Flexure Approach
    - Development is Needed to validate Flexures with Angled Flanges
      - Strength & Stiffness Verification is Required
      - Redo Flexure Interface tests (4 types) & Vibration Test



Remaining Work

- Shell
  - Qualification of 1522 Prepreg w/o Fire Retardant
  - Test Verification of Bottom Tile Flexure Scheme
  - Panel-to-Panel Joint Strength (In-progress)
  - Flexure Insert Strength (To be Verified)
- Flexures
  - Qualification of 1522 Prepreg w/o Fire Retardant
  - Bottom Tile Flexures qualification testing
  - Angled Flexure testing

GLAST Large Area Telescope:

AntiCoincidence Detector (ACD) Critical Design Review (CDR)

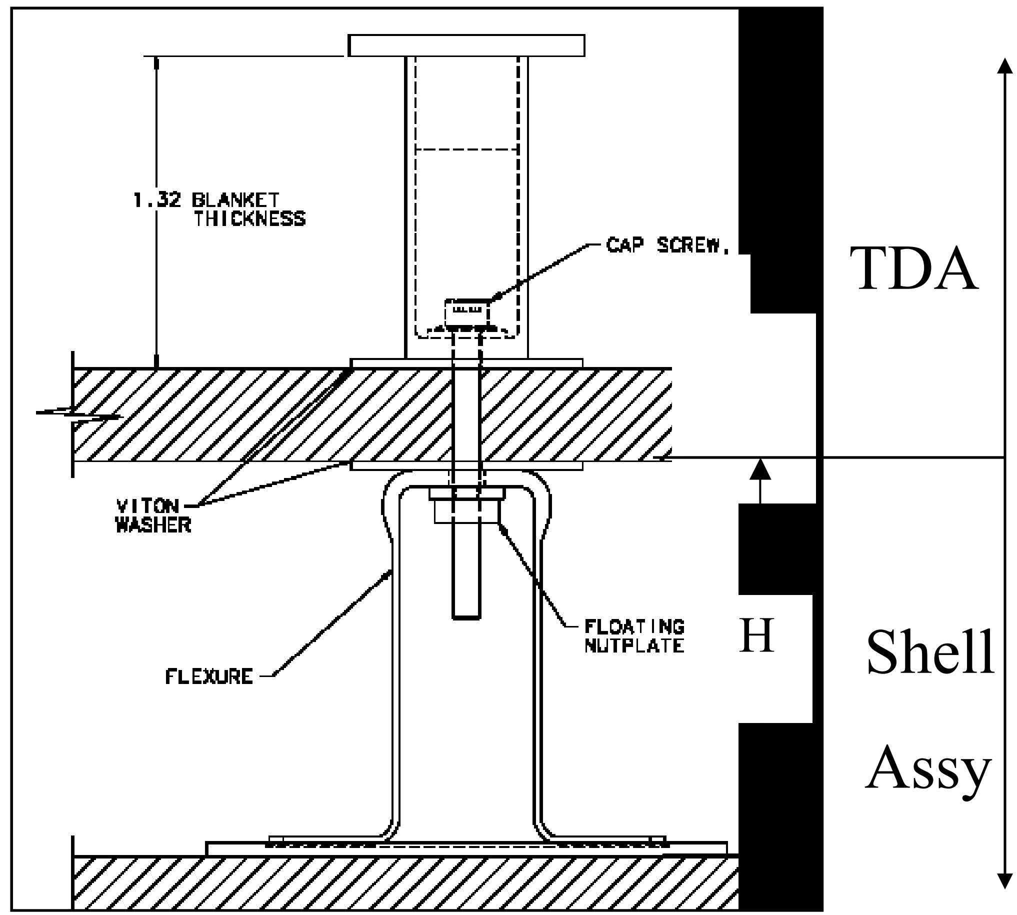
Tile Detector Assembly (TDA) Mechanical Mount Designs

Ken Segal
NASA Code 543.0
301-286-2895

NASA/Goddard Space Flight Center
January 7 & 8, 2003

TDA Mechanical Mount Designs

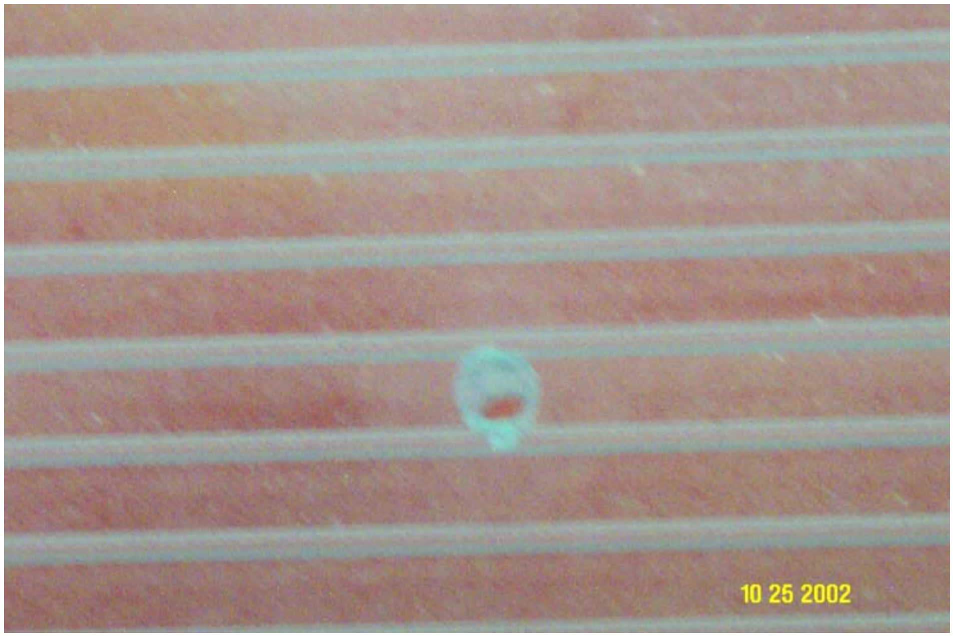
– **TDA Mechanical Design effort is defined as the mounting and placement for:**
  - **Tiles (Detectors)**
  - **Clear Fiber Cables (Light Transmitters)**
  - **Fiber Ribbons (Stop Gap Detector)**
  - **Thermal Blanket/ Micrometeoroid Shield**



TDA Mechanical Mount Design Drivers

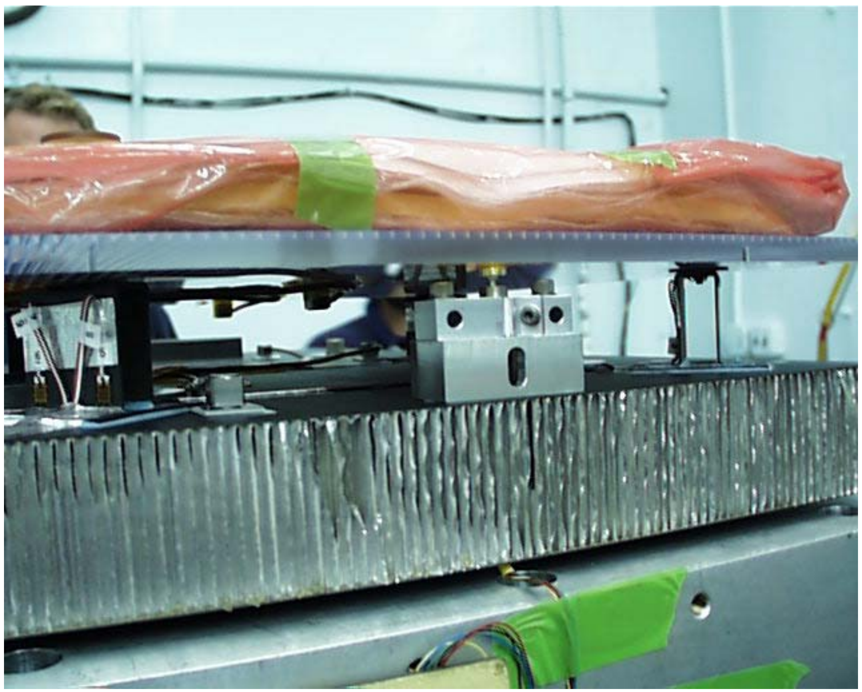
- Tile Detector Assemblies and Fiber Ribbon Detector Mounting
  - Mechanical
    - Design for Differential CTE between Fiber Ribbons and TSA
    - Provide for Blanket/Micrometeoroid Shield Mounting
    - Provide for Optical Cables Mounts on TSA
  - Limit Detection Performance Degradations
    - Prevent Detector Damage
    - Prevent Wrappings Damage
    - Minimize Tile Gaps

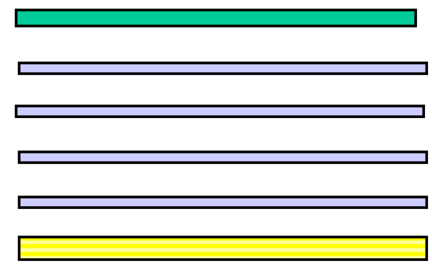
Tile Mount Design Constraint



- Optical Sensing Fiber Grooves Present-
    - Hole big enough for #4 (.112) fastener.

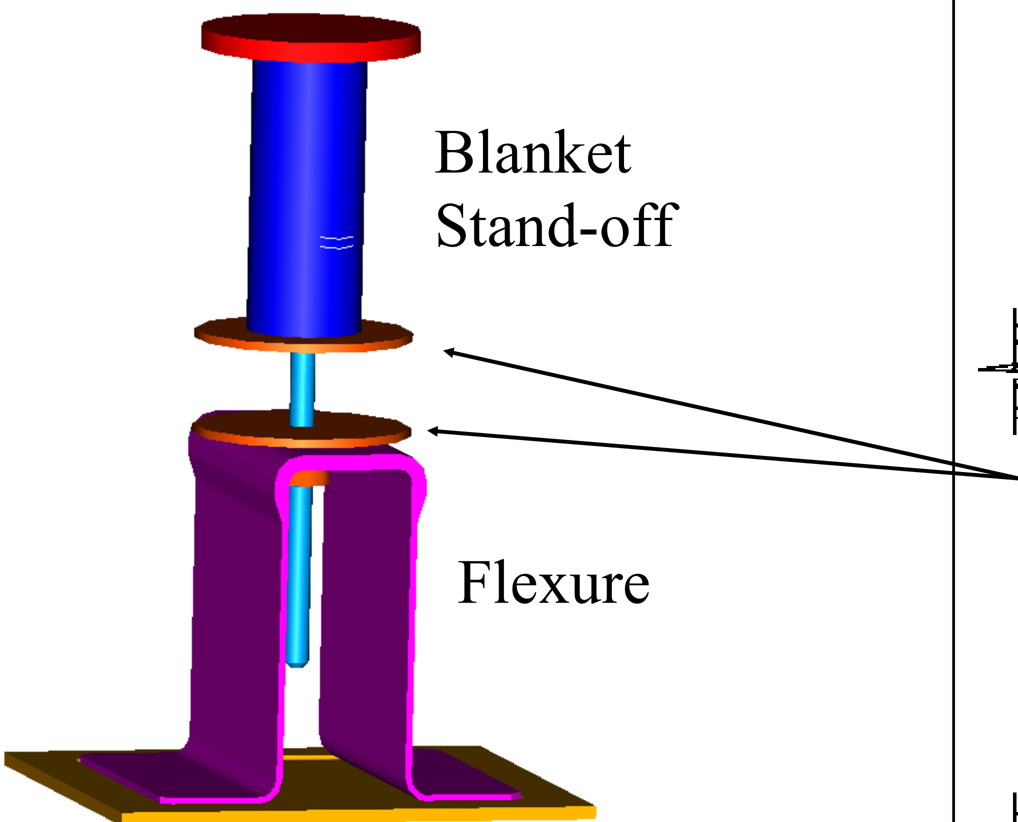
Thermal Blanket/ Micrometeoroid Shield

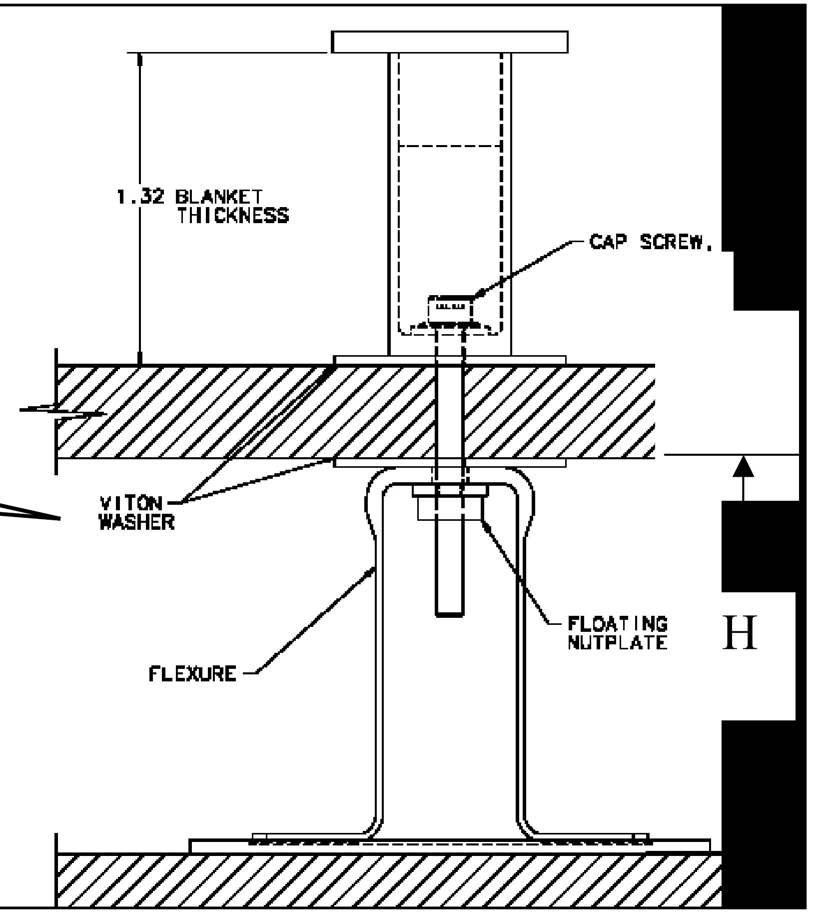




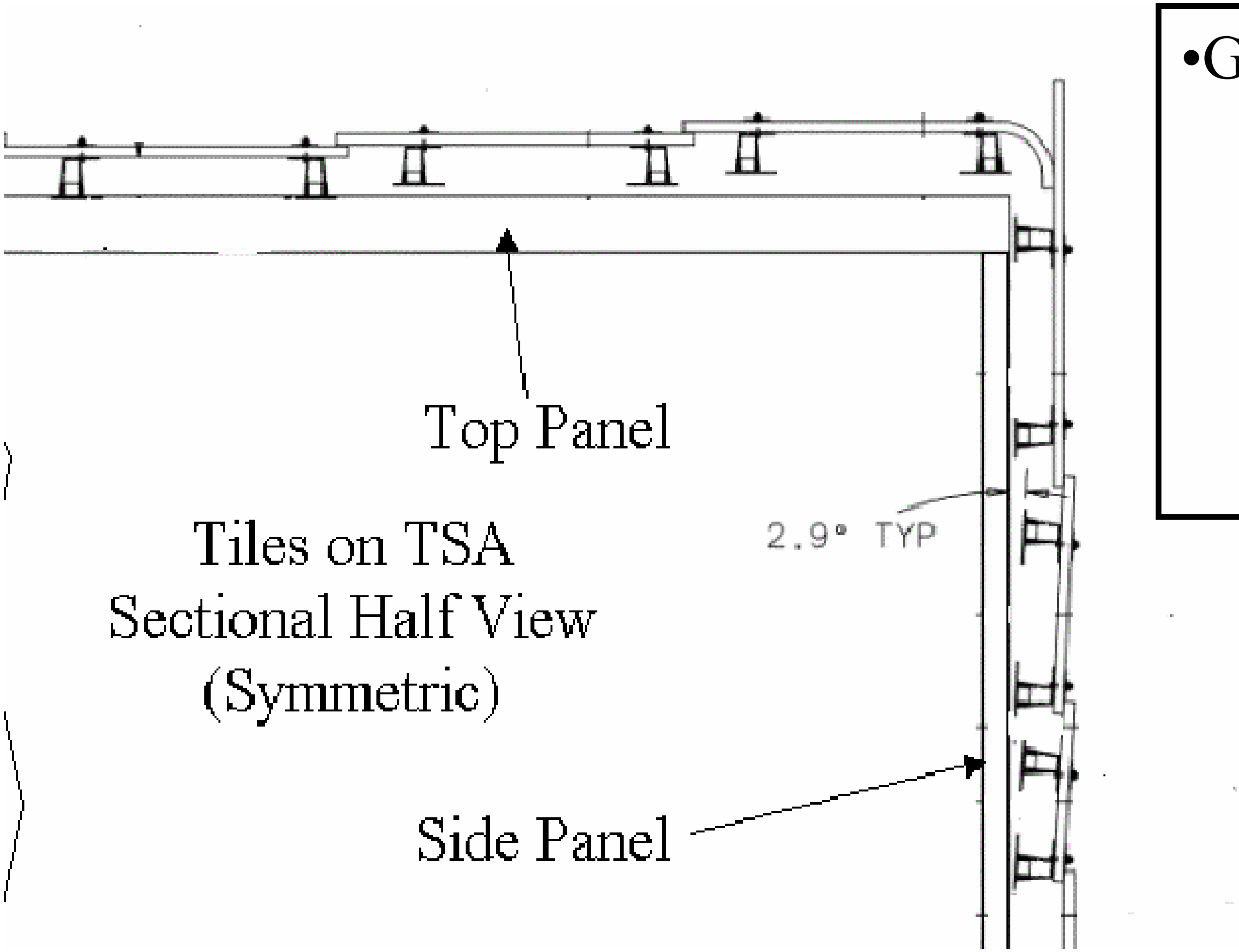
- Test Shield shown bagged to constrain layers
- No thermal blanket present

Tile and Blanket/Shield Mount Design



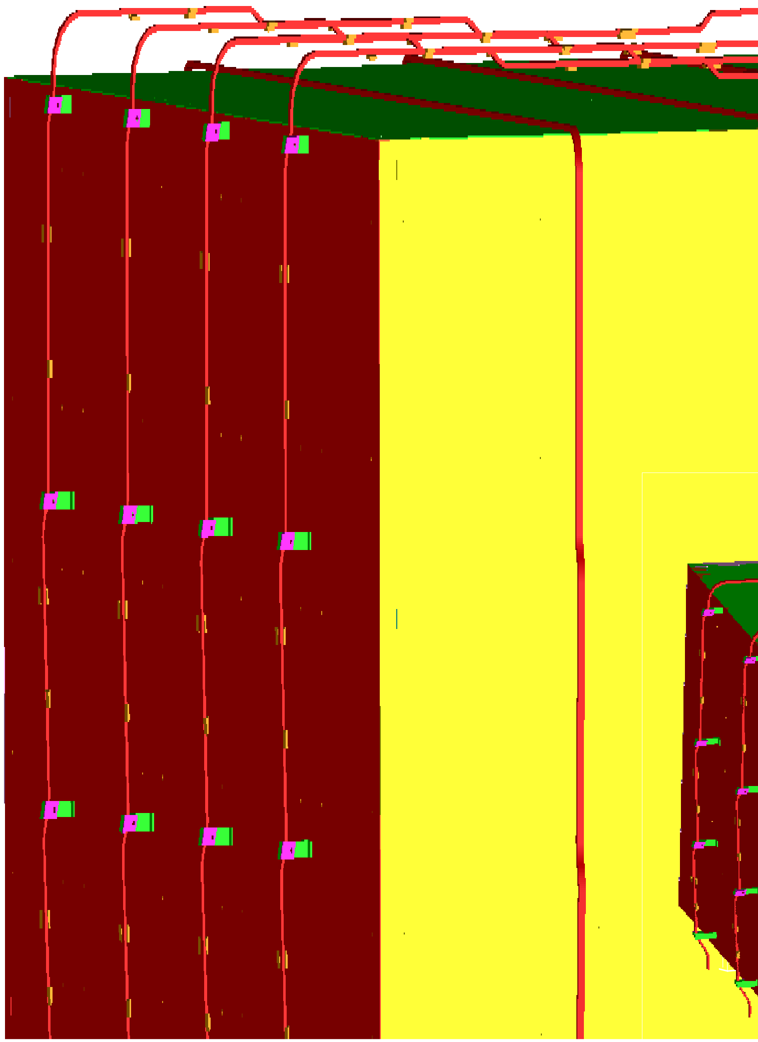


TDA Layout-Gaps



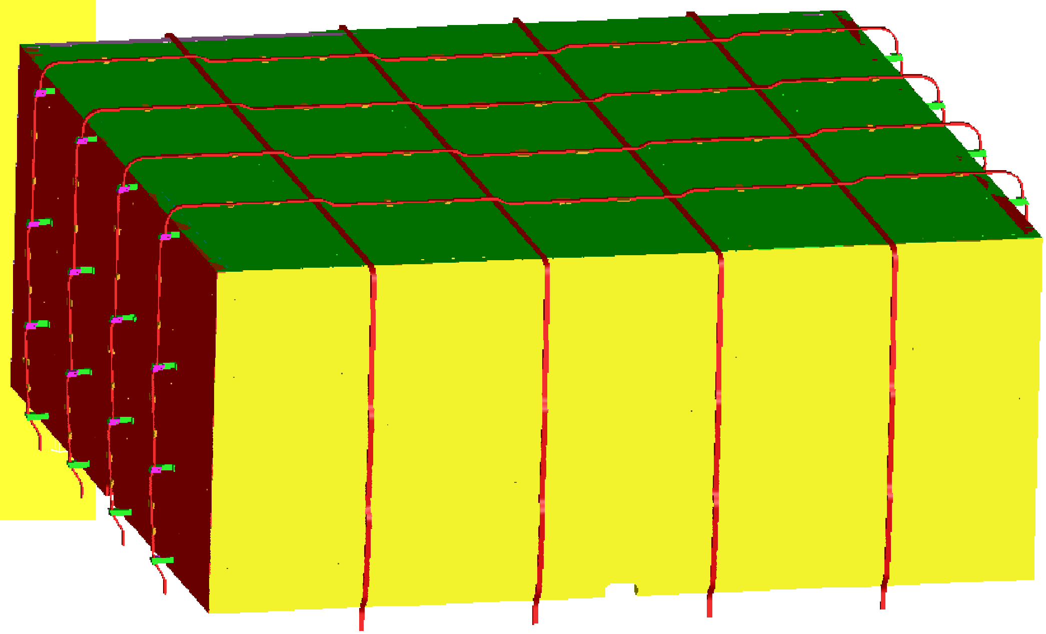
- GAPS
  - Tiles Overlap
  - Tiles Butt Together

Fiber Ribbon Mount Design



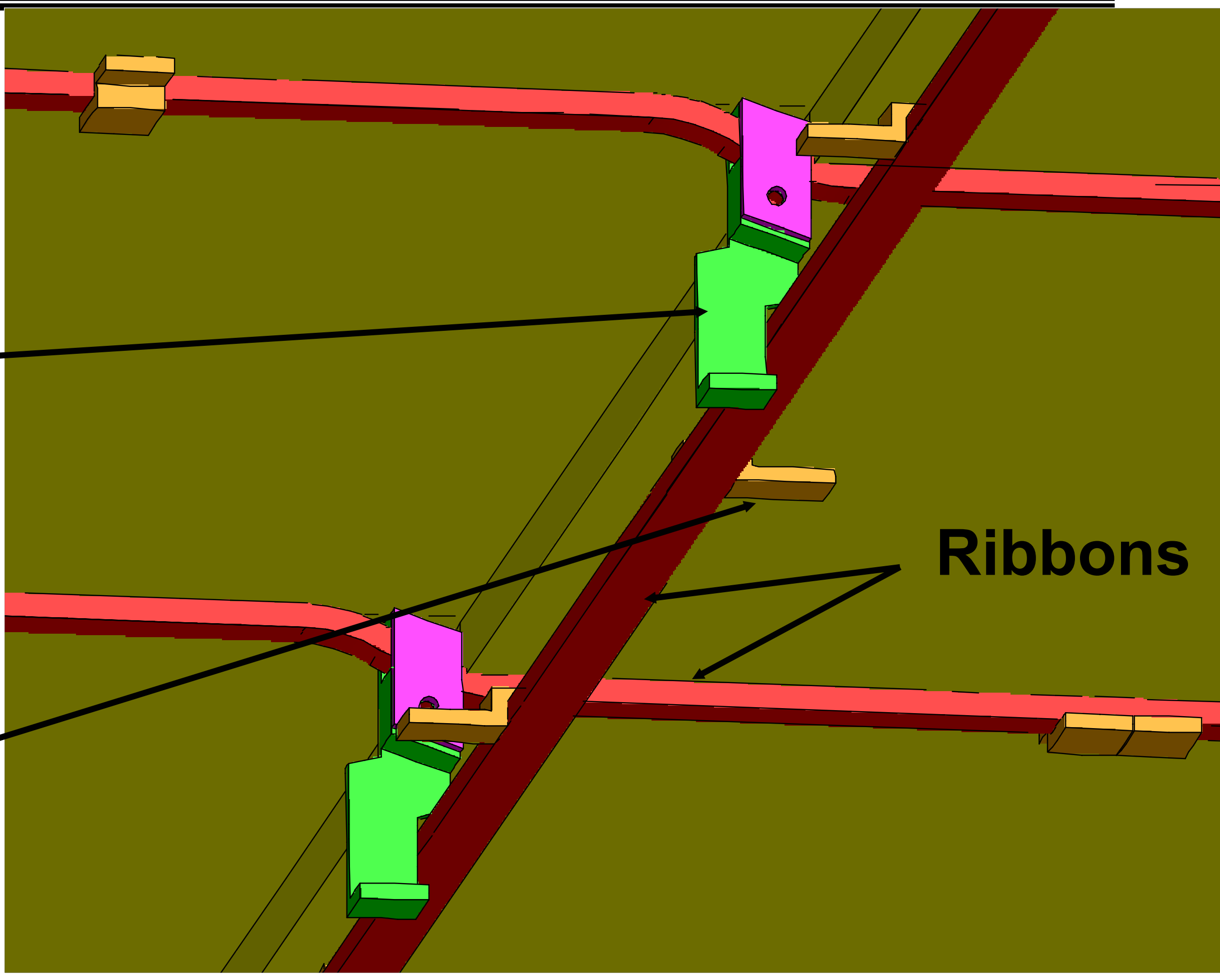
- 8 Fiber Ribbons detectors are for gaps between tiles butted together

- Ribbon mounts are thermally compliant design to allow ribbon thermal displacements

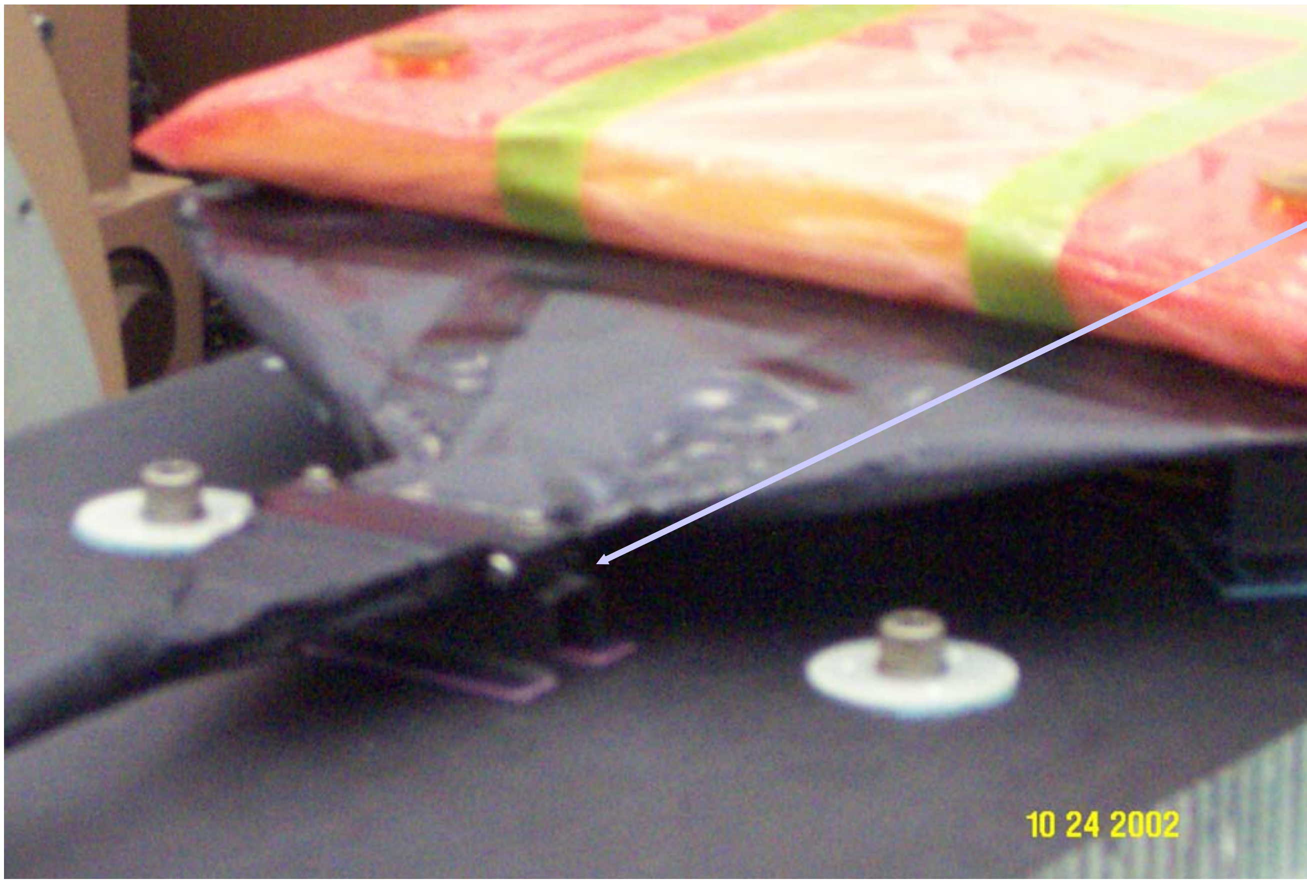


Fiber Ribbon Mount Design

- Ribbon Mounts Between Shell and Tiles
- Fixed Ribbon Mount
    - Attaches to Shell
    - Off-set for Cross Ribbon
- Tabs Tape to Tile Wrapping or to Shell- Allows Ribbon to Float



Tile Optical Connector Mount Design



Tile Optical Connector Mount

– –

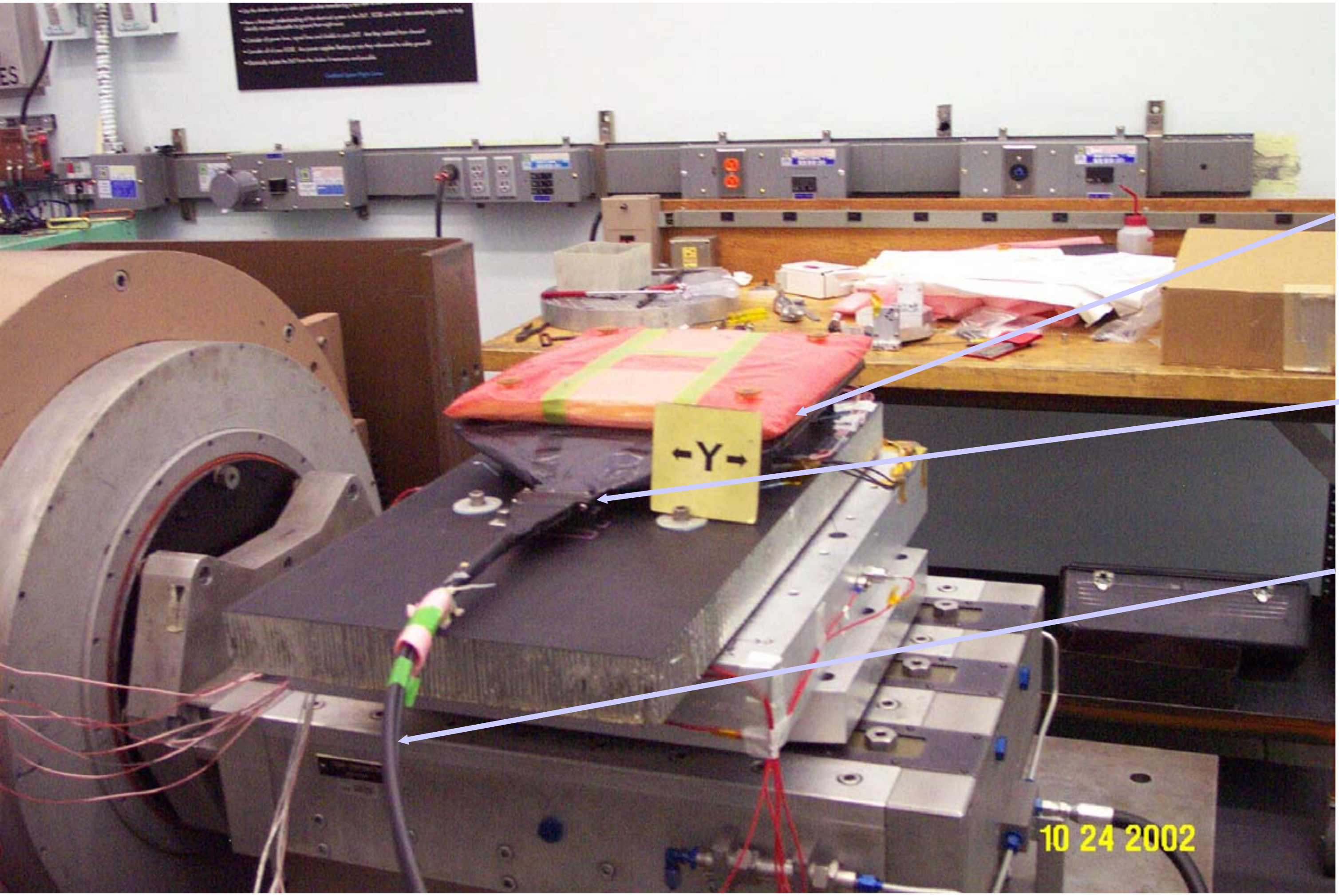
- Tile Flexure Design Basis
  - T300/1522 Cloth Laminate
  - Bonded to ACD Shell
- Optical connector fastens to the mount with fasteners.

ACD Mockup-
Cable Routing

ACD TSA and BEA structures modeled

Cable Routing Defined

TDA Mount Verification

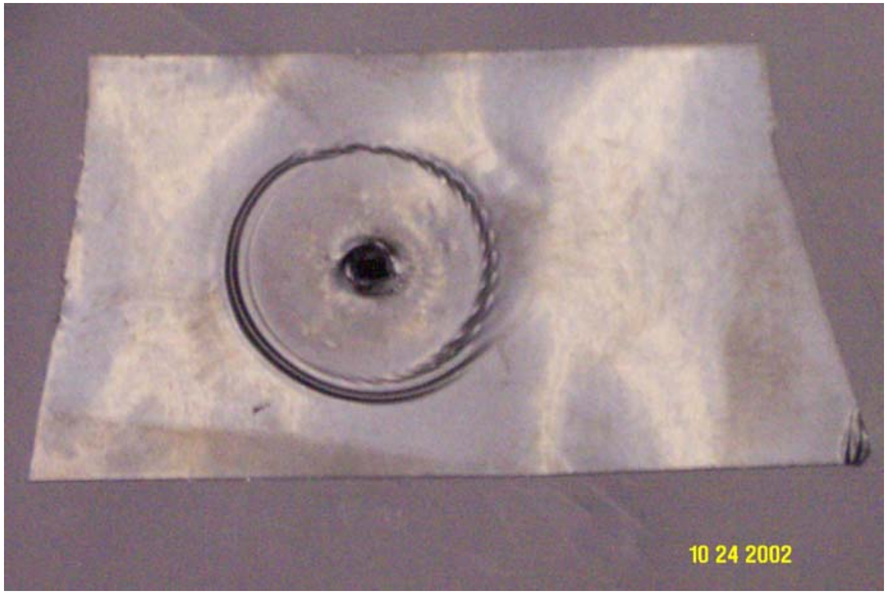


Wrapped Tile Detector

Optical Connector

Clear Fiber Cable

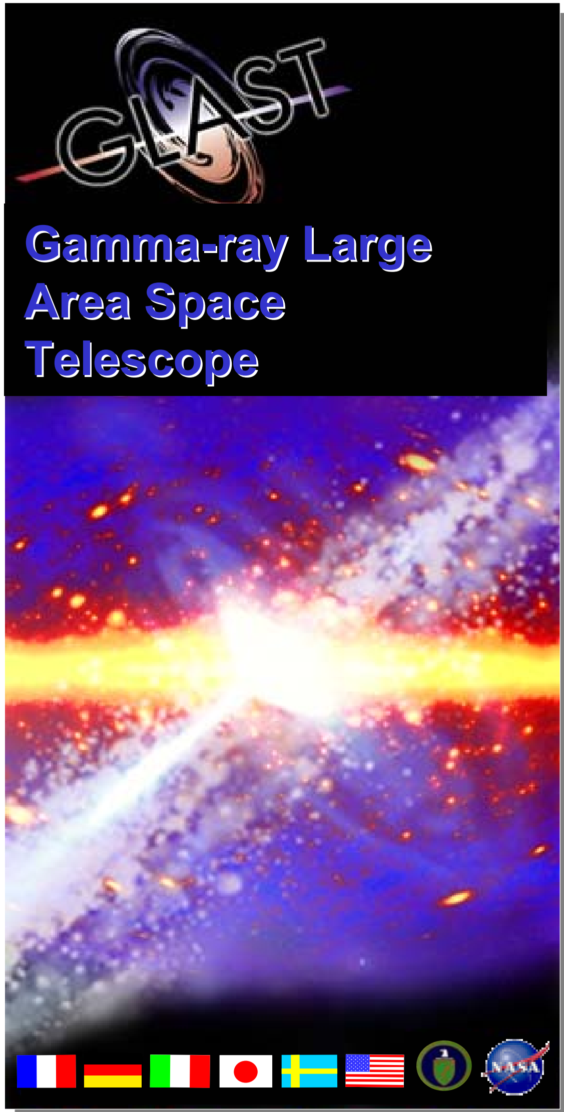
TDA Mount Verification



- **Vibration Testing Proved Mounting Robust**
  - **Pictured: Imprint left from blanket standoff on black kapton tape**
    - **No Tears**
  - **Tile to tile impact simulation**
    - **No Damage**
  - **Tile Shift**
    - **Less than 0.1mm shift measured.**

Remaining Work Open Issues

- Establish Final Tile Gaps
  - ACTION: Predicted tile gaps forwarded to science team for evaluation and approval.



GLAST Large Area Telescope:

AntiCoincidence Detector (ACD)

Critical Design Review (CDR)

Base Frame Assembly / Base Electronics Assembly (BFA/BEA)

Mechanical Design

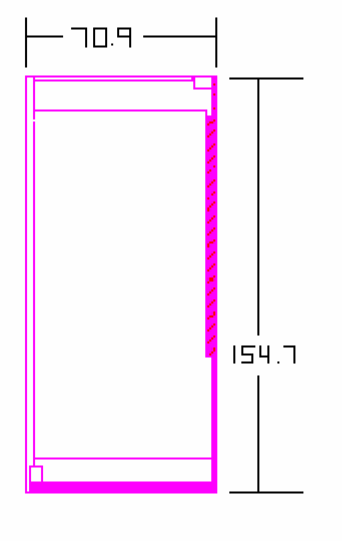
Ken Segal

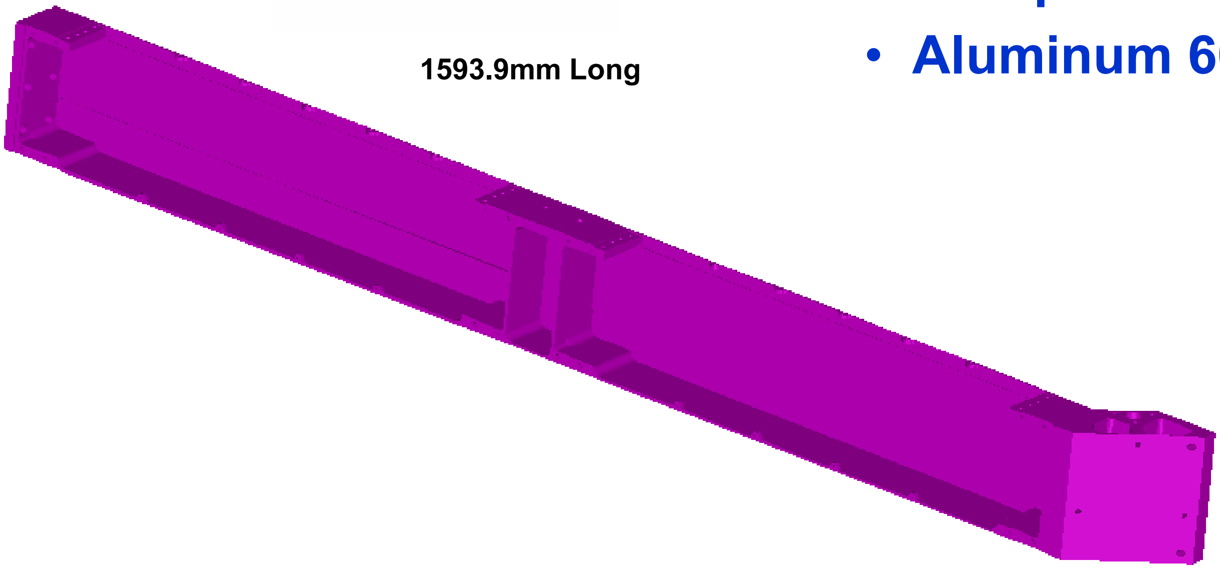
NASA/Goddard Space Flight Center
January 7 & 8, 2003

BFA Design Drivers

- Provide
  - LAT- ACD Mechanical and Thermal Interfaces
  - Volume and Mechanical Interface for ACD Electronics Chassis
    - EMI Shielding
    - Induce no stress into electronics components through the BFA to Electronics Chassis I/F
  - TSA to BEA Interface
  - MGSE Interfaces for ACD Processing and Lifting

BFA Design



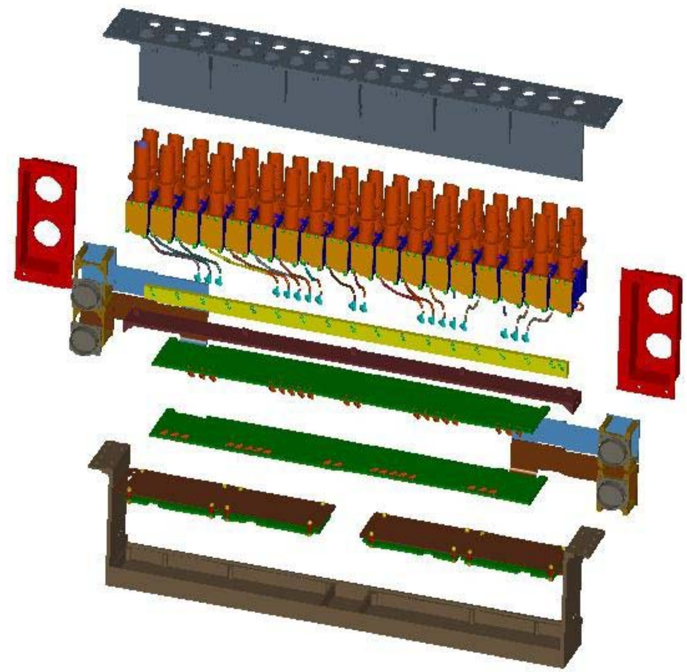


1593.9mm Long

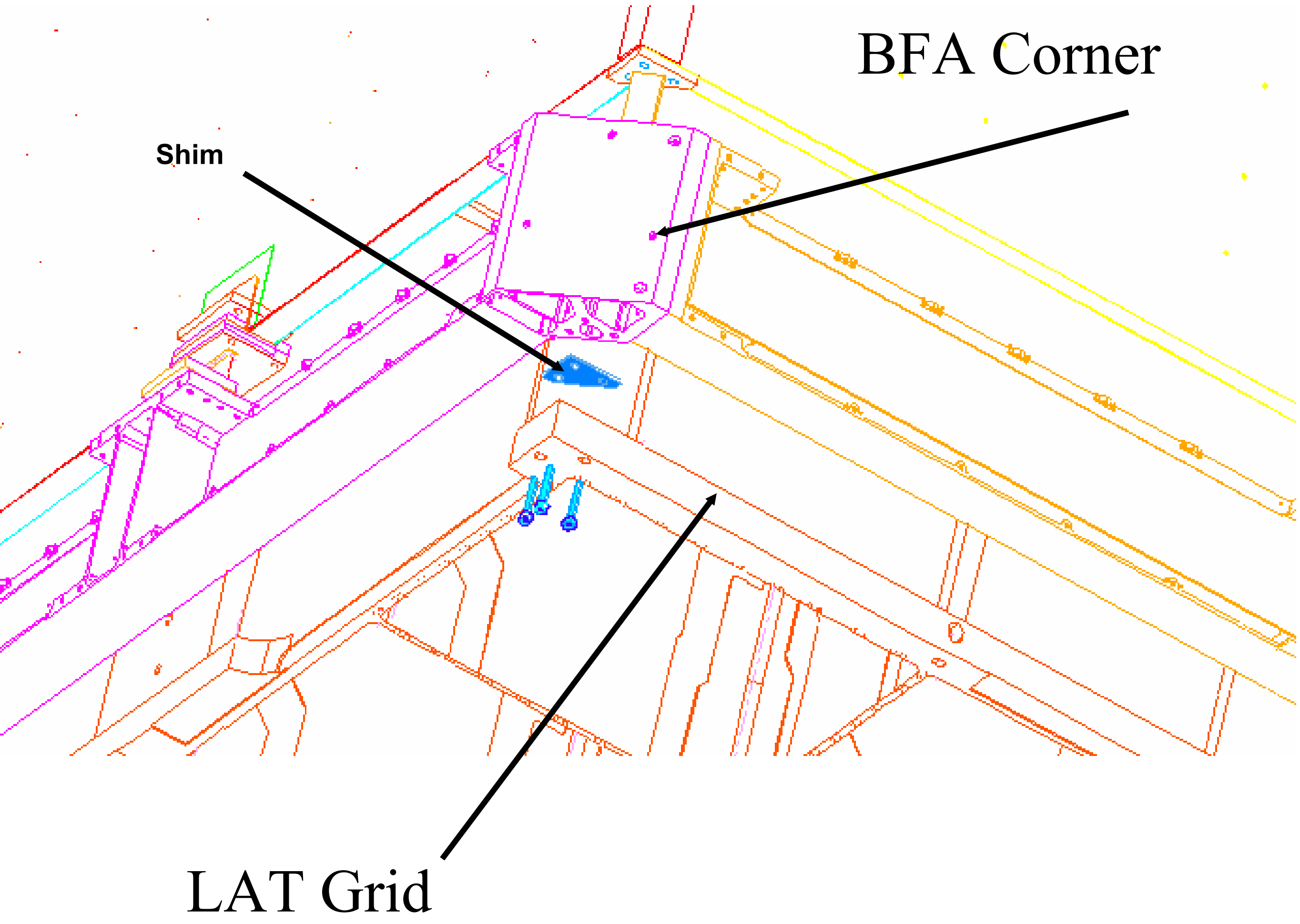
- BFA Channel
  - Basic element (1 of 4)
    - Provides volume for 2 ACD Electronics Chassis
    - Interfaces to LAT Grid at Midspans and Corners
    - Aluminum 6061-T651

BFA Design - I/F to ACD Electronics Chassis

- ACD Electronic Chassis Assembly is a stand-alone 'ACD Electronics Box'
  - Each ACD Electronics Chassis Assy is installed and removed from BFA
  - ACD Chassis designed to take minimum shear load through rail - without inducing loads into the electronic components
  - BFA Close-out Cover provides Chassis cavity closeout for EMI Shielding



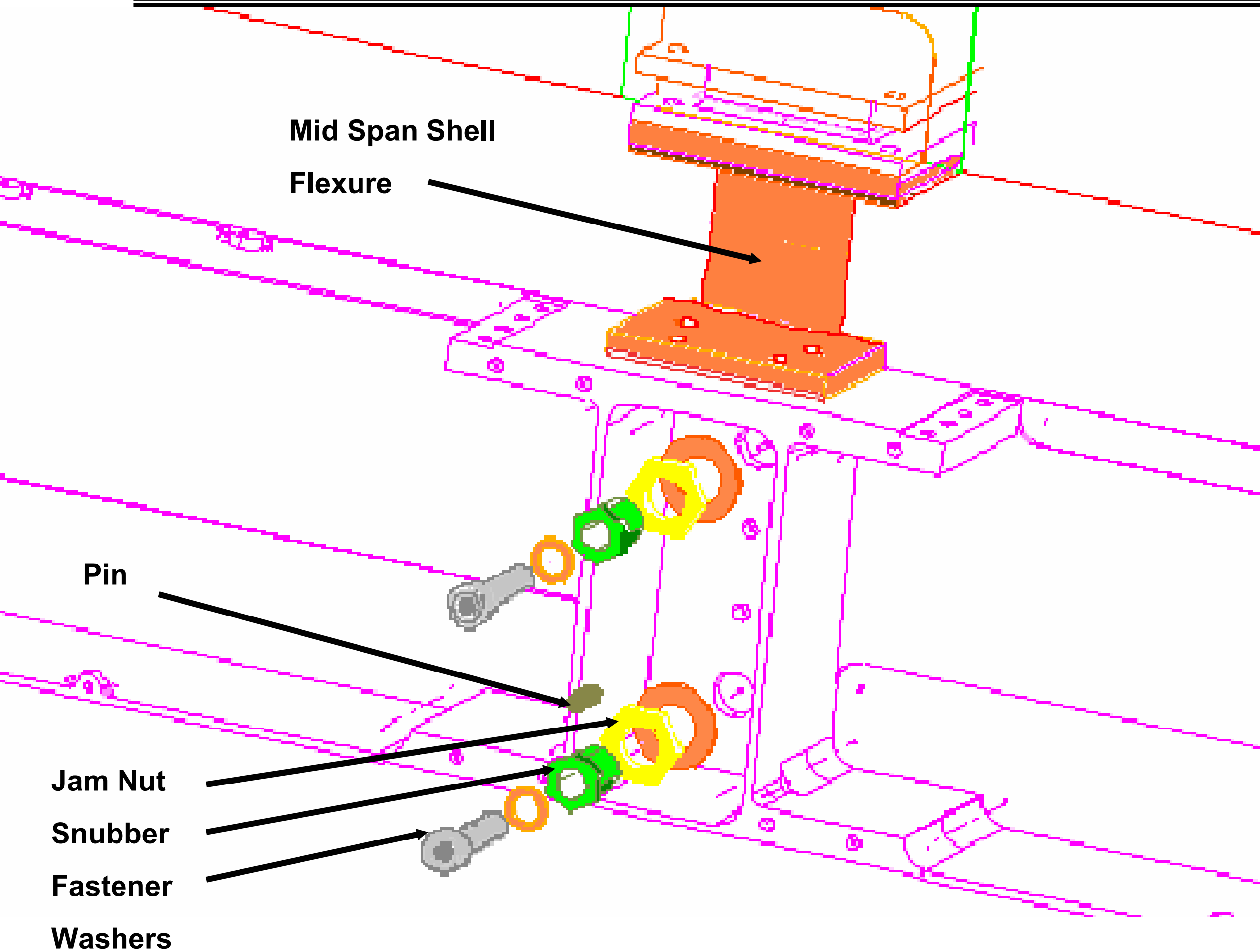
BFA Design



BFA connection to LAT Grid

- Connected in 4 corners
  - (3) ¼-28 x 1.5”
  - Shim.
- Registration to LAT Grid is planned via a pin and slot common to both the BFA and the LAT Grid.

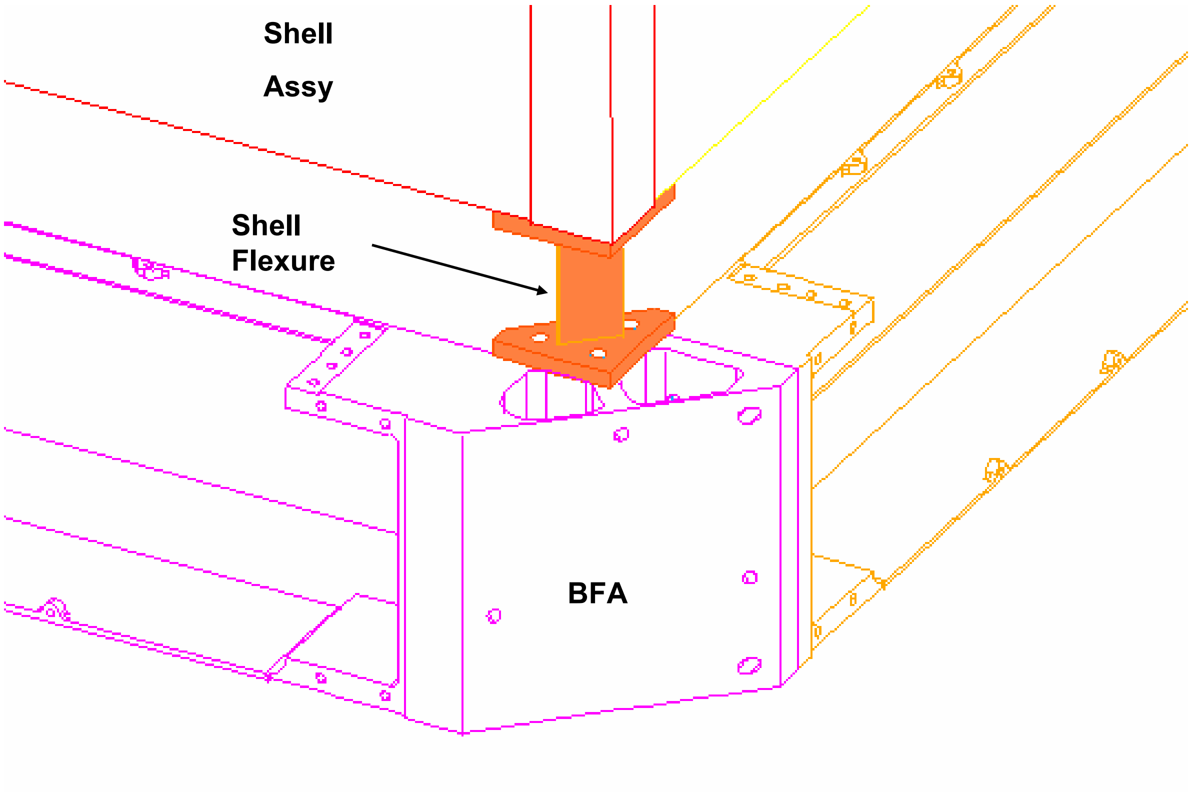
BFA Design



BFA connection to LAT Grid

- At each of 4 mid-span locations
  - (2) 3/8-24 x 1.5” fasteners
  - 3/8 x 1.0” slip fit pin
- Gap Between ACD and LAT Grid is taken up with adjustable snubbers.
- Pin holes match drilled to LAT Grid after BFA is completed.
  - Pin is captured to accommodate slip fit.

BFA Design



BFA connection to TSA

- Shell Flexures attach BFA to Shell Assembly in each corner, and at each midspan location (previous slide)
- 1/4-28 x 0.75 UNF fits through Clearance holes in shell flexure to both the Shell and BFA.

Remaining Work – Open Issues

Volume for Electronics Chassis in the BFA not verified.

- Electronics Need to fit into the BFA Volume.
  - 3-D Design Model Shows all components fit.
  - Harnessing is partially modeled.

- **ACTION PLAN:** Build Electronics Chassis Development Unit for fit checks using electronics development units.

- **AFFECT:** Will not start BFA flight fabrication until the fit checks are complete.

Remaining Work – Open Issues

- **<u>LAT-ACD IDD Not Completed</u>**
  - **ACTION PLAN:** **ACD Mechanical Team is working with LAT Team to complete and agreed to a LAT-ACD IDD.**
  - **AFFECTS:** **BFA Designs can not be completed until IDD is signed off.**

GLAST Large Area Telescope:

AntiCoincidence Detector (ACD)

Critical Design Review (CDR)

Tile Shell Assembly (TSA) Mechanical Analyses

Sheila Wall
GSFC Code 542
301-286-7125

NASA/Goddard Space Flight Center
January 7 & 8, 2003

ACD CDR
Tile Shell Assembly Analyses

REQUIREMENTS

- Minimum Frequency of 50 Hz.
- Demonstrate positive Margins of Safety under Design Loads

ACD CDR -
ACD Design Limit Loads

Summary of ACD Design Limit Loads				
CASE	***MECHANICAL LOADS***			***COMPONENTS VALIDATED***
Lift-off *	Thrust: 4.1 G	Lateral: 5.1 G	Combined	ALL
MECO *	Thrust:6.8 G	Lateral: 0.2 G	Combined	ALL
Vibro-Acoustic	Thrust: 30 G	Lateral: 30 G	Single Axis	CHASSIS
	Thrust: 7 G	Lateral: 7 G	Single Axis	BFA
	Normal: 4.6 G	Lateral: 4.0 G	Combined	SIDE PANELS
	Normal: 6.5 G	Lateral: 4.0 G	Combined	TOP PANEL
	Normal: 17 G	Lateral: 12 G	Single Axis	TDA
ACD Lift	Thrust: 1.6 G			BFA
Handling	10 LB in any direction			TDA
THERMAL LOADS				
Extreme Cold Temperature	-40 C			ALL
Extreme Warm Temperature	+45 C			ALL

*** Event consist of eight load cases, the lateral load is applied in 45° increments simultaneous with the thrust load.**

ACD CDR - ACD Design Limit Loads

Interface Forces - Design Limit Loads [1]

ACD-Grid Interface Location	Shear (N)	Tension (N) / Compression (N)
Mid-Span	4402	2223
Corner	0	1787

Nastran LAT FEM

Load Case / Location	4.1 G Z and 5.1 G X			4.1 G Z+cos(45)*5.1+sin(45)*5.1			6.8 G Z and 0.2 X		
Corners	X	Y	Z	X	Y	Z	X	Y	Z
+X,-Y	0	0	1023	0	0	-68	0	0	-271
+X,+Y	0	0	1028	0	0	1403	0	0	-270
-X,+Y	0	0	-1407	0	0	-318	0	0	-365
-X,-Y	0	0	-1411	0	0	-1787	0	0	-363
Mid-Spans									
+X	283	-8	3324	319	-2666	2915	675	19	3259
+X	-1532	13	1936	-1254	-2003	1769	-1027	-17	2266
-X	-536	-17	538	-501	-2673	947	-680	1	3145
-X	-338	16	769	-61	-2004	937	949	-2	2219
+Y	-3943	408	1947	-2777	330	3061	-150	670	3224
+Y	-2686	-599	1339	-1911	-1285	1854	-109	-984	2224
-Y	-3951	-404	1941	-2784	-485	827	-157	-673	3225
-Y	-2684	590	1343	-1912	-95	828	-106	988	2223

Ansys LAT FEM

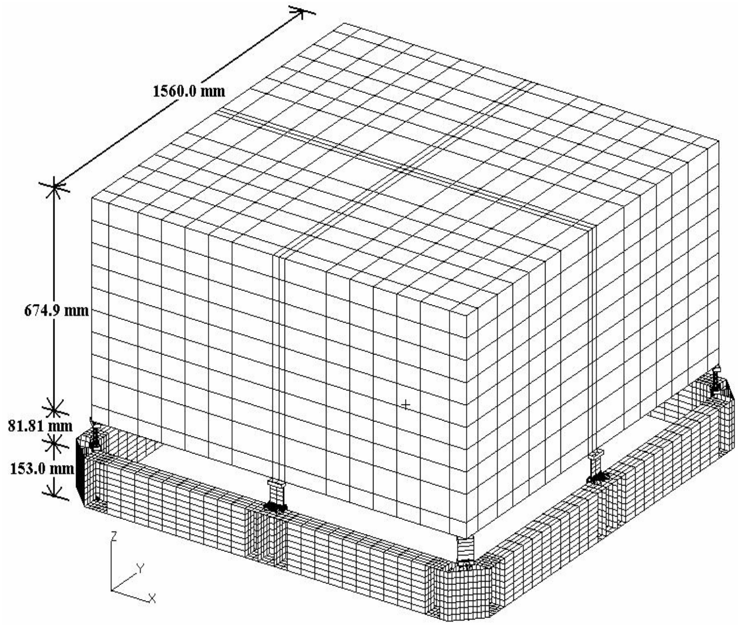
Load Case / Location	4.1 G Z and 5.1 G X			4.1 G Z+cos(45)*5.1+sin(45)*5.1			6.8 G Z and 0.2 X		
Corners	X	Y	Z	X	Y	Z	X	Y	Z
+X,-Y	0	0	832	0	0	27	0	0	-113
+X,+Y	0	0	833	0	0	1097	0	0	-112
-X,+Y	0	0	-1011	0	0	-206	0	0	-184
-X,-Y	0	0	-1011	0	0	-1275	0	0	-183
Mid-Spans									
-X	746	0	-1910	695	-2064	-1731	952	0	-2169
-X	-1649	0	-1648	-1365	-1400	-1431	-1162	0	-1534
+X	-394	0	-676	-445	-2064	-855	-938	0	-2120
+X	-294	0	-166	-10	-1400	-384	1086	0	-1475
-Y	-2979	571	-1278	-2107	740	-1825	-117	948	-2123
-Y	-1932	-679	-931	-1366	-1419	-1569	-75	-1127	-1541
+Y	-2979	-572	-1281	-2106	-403	-734	-117	-948	-2123
+Y	-1933	680	-928	-1367	-60	-289	-76	1127	-1541

NOTE: Metric Units

1) ACD-LAT Interface Control Document (ICD)-Mechanical, Thermal and Electrical, LAT-SS-00363, Tbl 6.5 Structural Interface Loads

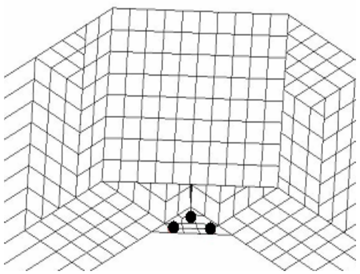
ACD FINITE ELEMENT MODEL

- TSA
  - –Honeycomb Composite
    - PSHELL Elements
  - –Tile Detector Assembly
    - NSM
  - –Micrometeoroid/Thermal Blanket
    - NSM
- TSA Flexures
  - –PBAR Elements
- BEA
  - –BFA
    - PSHELL Elements
  - –Electronics Bay (Chassis)
    - PSHELL Elements
  - –PMTs and Electronics
    - NSM

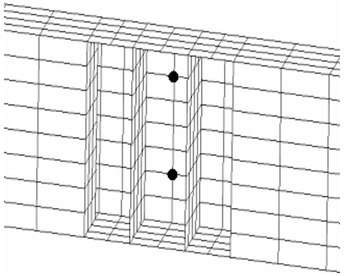


ACD Boundary Conditions

NOTE: TSA dimensions are referenced to centerline.



Corner B.C., 1 DOF



Mid-Span B.C., 3 DOF

ACD CDR
Tile Shell Assembly Analyses

ACD FINITE ELEMENT MODEL

Mass Breakdown of ACD

Component	Mass Report (kg)	FEM (kg)
TSA/TDA/ Blankets	193.0	200.3
Flexures	7.6	7.7
BEA	69.6	71.2
TOTAL	270.2	279.2

•10% Mass Contingency was included in analysis.

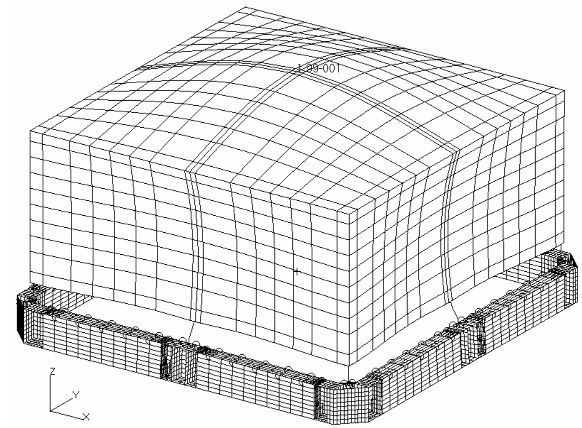
C.G. Location in Basic Coordinate System

Mass Axis	Mass (kg)	X cg (m)	Y cg (m)	Z cg (m)
X	279.6	0.0	-6.65E-06	3.30E-01
Y	279.6	4.95E-06	0.0	3.30E-01
Z	279.6	4.95E-06	-6.65E-06	0.0

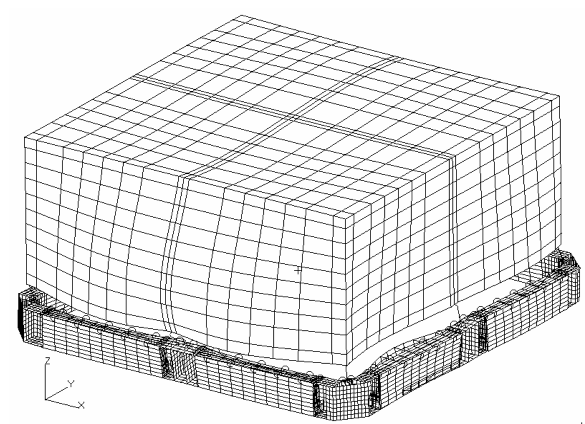
NOTE: Validity checks were performed on the FEM.

ACD MODAL ANALYSIS

MODAL EFFECTIVE MASS							
MODE NO.	FREQUENCY	T1	T2	T3	R1	R2	R3
1	56.06	0.00	0.00	46.42	0.00	0.00	0.00
2	61.89	0.02	166.12	0.00	0.31	0.00	0.00
3	62.00	163.40	0.02	0.00	0.00	32.47	0.00
4	62.91	0.00	0.00	0.00	0.00	0.00	0.00
5	73.30	0.01	0.04	0.00	0.00	0.00	6.21
6	73.48	0.00	6.50	0.00	0.00	0.00	0.03
7	73.63	7.81	0.00	0.00	0.00	1.43	0.01
8	74.00	0.01	0.00	0.00	0.00	0.00	0.00
9	74.20	0.14	0.04	0.00	0.00	0.21	0.01
10	74.23	0.00	0.01	0.00	0.00	0.13	0.10
	TOTAL	171.41	172.73	46.42	0.31	34.25	6.36



1st Mode – 56.06 Hz, Drumhead Mode of TSA Top Panel



2nd Mode – 61.89 Hz, Translation Mode of TSA

ACD CDR
Tile Shell Assembly Analyses

Flexure Information

- Flexure Failure Modes Analyzed
  - Compressive Stability
  - Weak Axis Strength
  - Strong Axis Stability/Strong Axis Strength

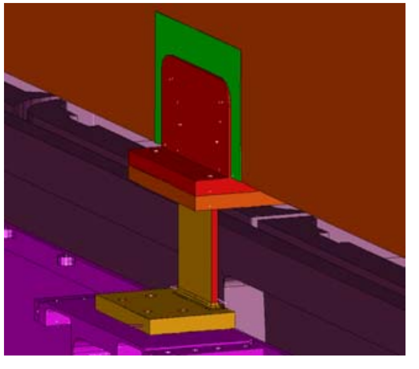
Flexure Dimensions

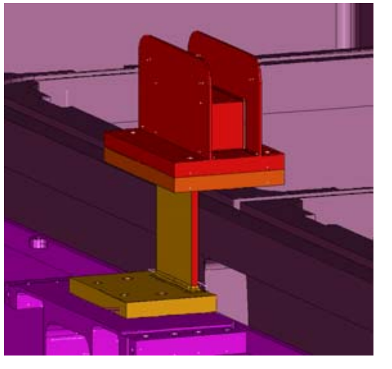
Section	Metric (m)	English (in)
Blade Height	0.060	2.36
Blade Width	0.056	2.20
Blade Thickness	0.0038	0.15

- Interaction Margin of Safety Equation

$$MS := \frac{1}{Pcolumn_{ratio} + Mweak_{ratio} + \max(Strong\_shear\_stability_{ratio}, Mstrong_{ratio})} - 1$$

- Analysis Safety Factors (S.F.)
  - Tested Metallic Parts
    - Ultimate, 1.4
    - Yield, 1.25
  - Un-Tested Metallic Parts
    - Ultimate, 2.6
    - Yield, 2.0
  - Composite Parts
    - 1.5





Mid-Span Flexure Illustrations

ACD CDR
Tile Shell Assembly Analyses

Margins of Safety Summary

Static

Flexure	Blade	Transverse Shear (Failure Mode of Core @ Flexure Location)	Shell Flexure Insert Block to Facesheet Bond
Corner	+1.47	+0.1 (w/potting)	+0.54
Mid-Span	+0.52	+0.3 (w/o potting)	+0.17

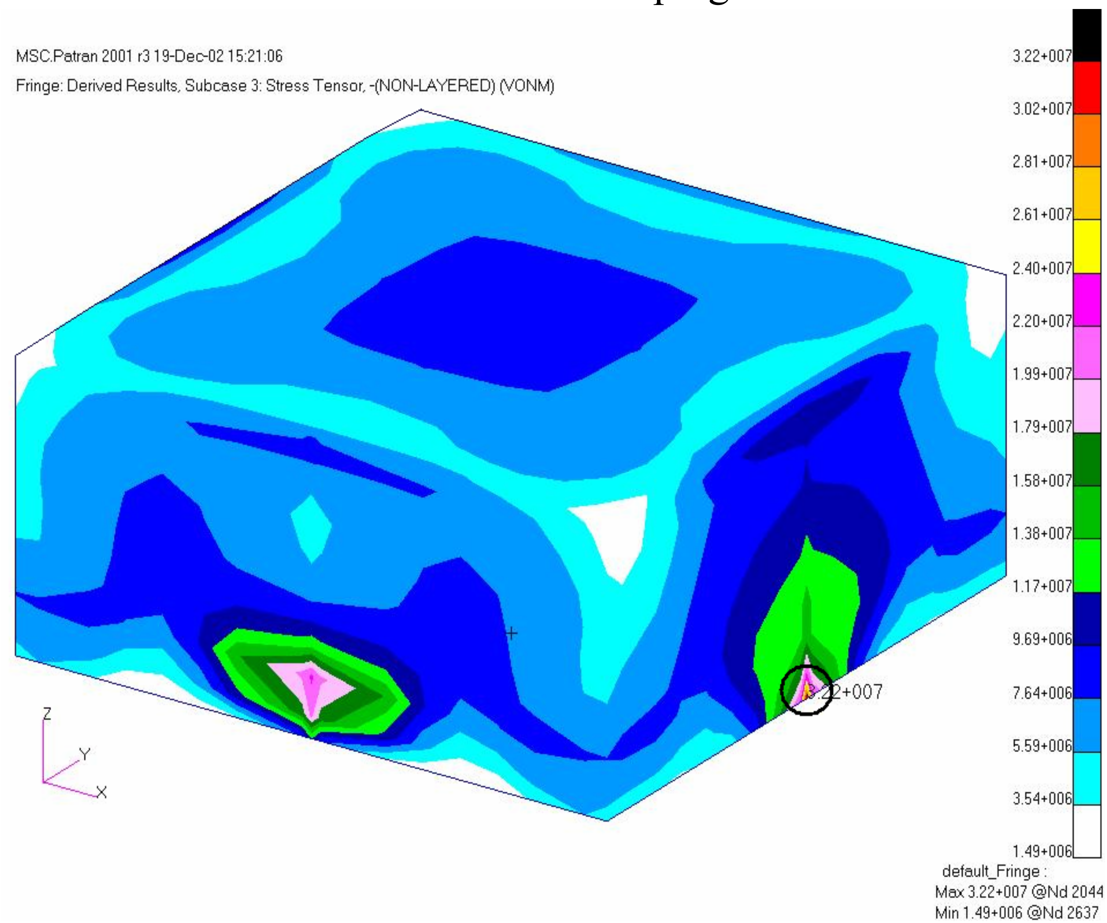
Thermal

Flexure	Blade	Transverse Shear (Failure Mode of Core @ Flexure Location)	Shell Flexure Insert Block to Facesheet Bond
Corner	+1.44	+0.16 (w/potting)	+0.05
Mid-Span	+0.95	+2.36 (w/o potting)	>20.0

ACD CDR
Tile Shell Assembly Analyses

Stress Contour of Tile Shell Assembly (Pa)

•Maximum VonMises Stress enveloping all Static Load Cases



-Strength M.S.

$$MS := \frac{Fcu}{f_{actual} \cdot SF_{composite}} - 1$$

MS = +3.85

-Dimpling M.S.

$$\sigma_{cr\_dimp} := \frac{2 \cdot E_f}{\left(1 - \nu^2\right)} \cdot \left(\frac{t_f}{s}\right)^2 \quad *$$

$$MS := \frac{\sigma_{cr\_dimp\_metric}}{\sigma_{von} \cdot 1.5} - 1$$

MS = +42.4

-Wrinkling M.S.

$$\sigma_{cr\_wrink} := 0.82 \cdot E_f \cdot \sqrt{\frac{E_c \cdot t_f}{E_f \cdot h1}} \quad *$$

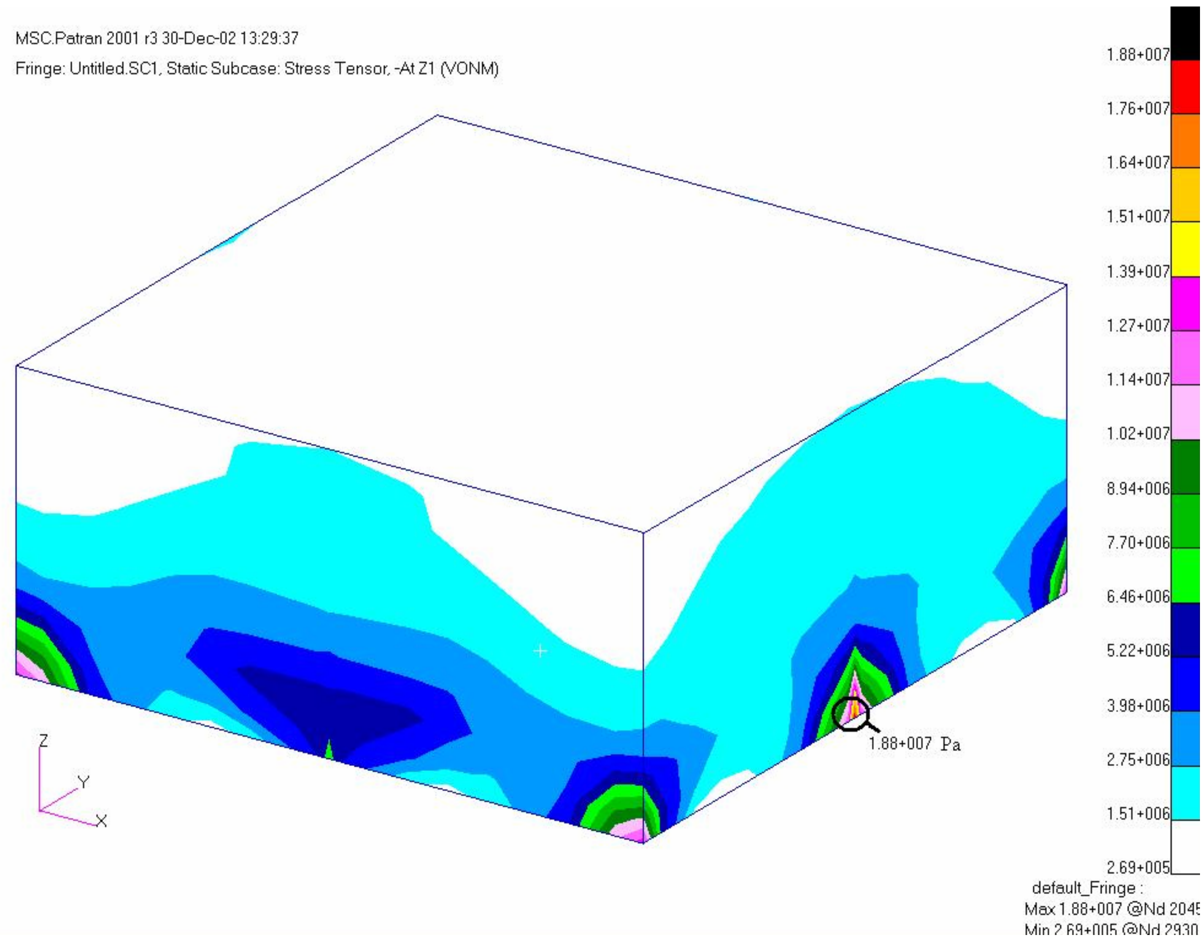
$$MS := \frac{\sigma_{cr\_wrink\_metric}}{\sigma_{von} \cdot 1.5} - 1$$

MS = +4.73

* HEXCEL Design Handbook TSB124 p. 12

ACD CDR
Tile Shell Assembly Analyses

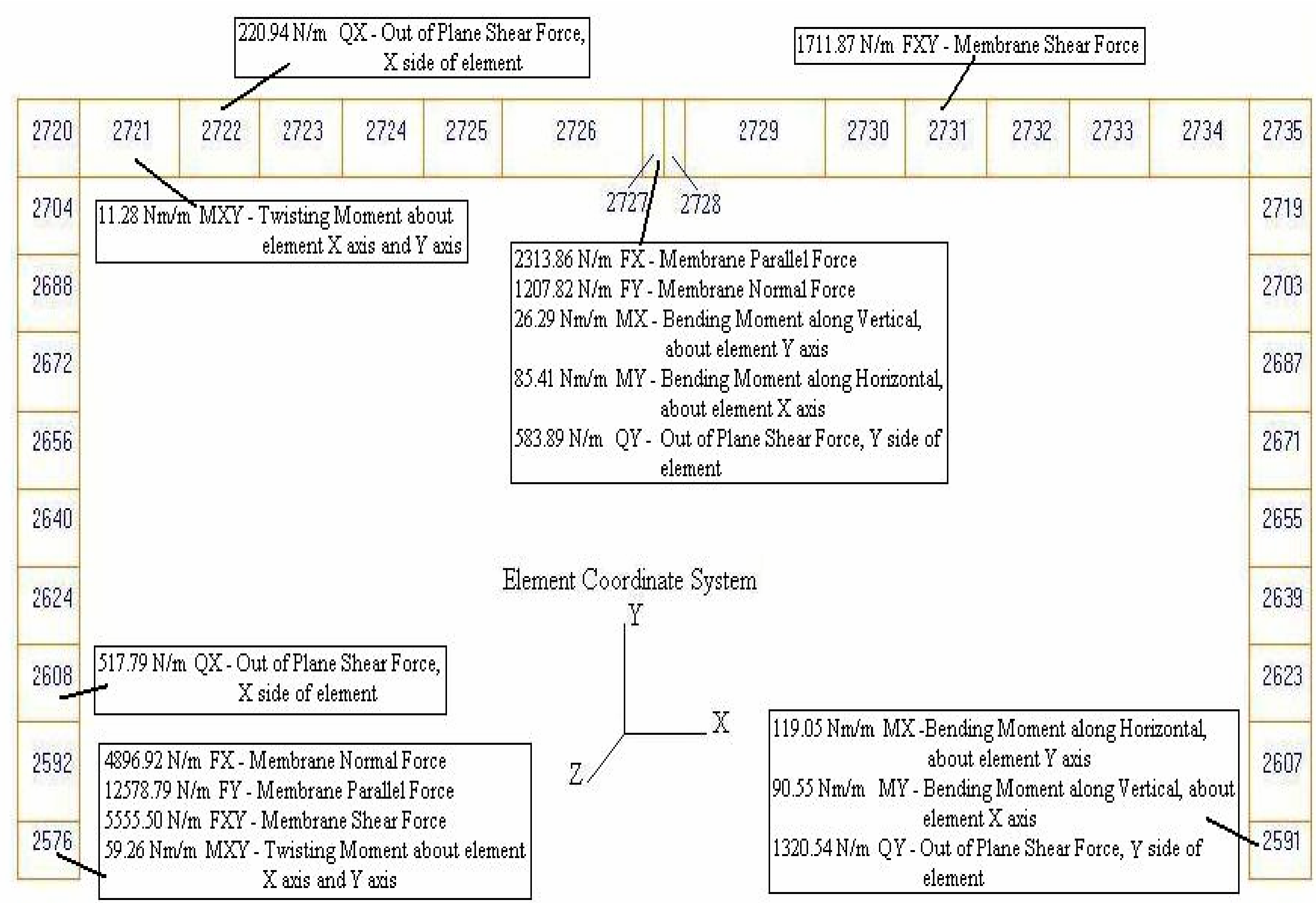
Stress Contour of Tile Shell Assembly (Pa)

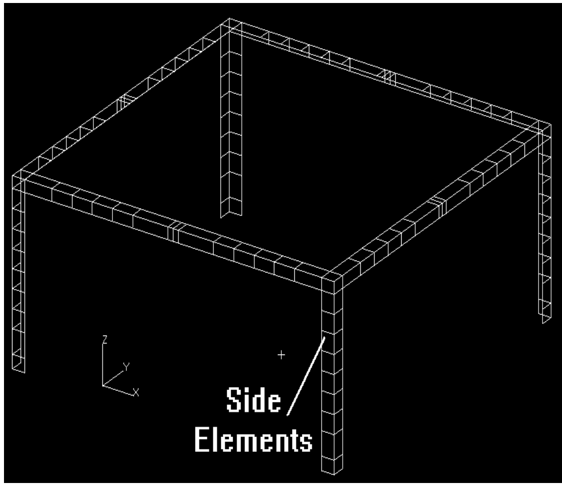


- Maximum VonMises Stress Thermal Load Case
- Stresses enveloped by Static Load Cases

ACD CDR
Tile Shell Assembly Analyses

Joint Forces and Moments For Side Panel of TSA (Metric)





ACD CDR
Tile Shell Assembly Analyses

Conclusions

- Fundamental Frequency is above 50 Hz.
- All Strength Margins are positive.

Remaining Work

- Obtain TSA Joint allowable and determine Margins of Safety for panel joints (in-progress)

ACD CDR
Tile Shell Assembly Analyses

Back-up

ACD FINITE ELEMENT MODEL

Inertia Matrix about Origin of Basic Coordinate System

279.6	0.0	0.0	0.0	92.2	0.002
0.0	279.6	0.0	-92.2	0.0	0.001
0.0	0.0	279.6	-0.002	-0.001	0.0
0.0	-92.2	-0.002	163.0	0.001	0.0
92.2	0.0	-0.001	0.001	163.0	0.0
0.002	0.001	0.0	0.0	0.0	203.3

GLAST Large Area Telescope:

AntiCoincidence Detector (ACD)

Critical Design Review (CDR)

Tile Detector Assembly (TDA) Structural Analysis

Cengiz Kunt
Swales Aerospace
301-902-4214

NASA/Goddard Space Flight Center
January 7 & 8, 2003

Structural Requirements & Compliance

Structural Integrity

- Demonstrate positive Margins of Safety (MS) for all TDA assemblies and parts under quasi-static, vibro-acoustic, and thermal environments and handling loads
- Compliance by a combination of Test (ACD All-up Acoustic Test), Analysis, and Similarity
- Analysis based on test correlated Finite Element Models
- Analysis Safety Factors (SF):
  - Tested Metallic Parts: 1.4 for ultimate and 1.25 for yield
  - Un-Tested Metallic Parts: 2.6 for ult and 2.0 for yld
  - Composite Material Parts: SF=1.5
- Service Life: No degradation of structural performance during the 5 years of orbital operation (design against fatigue, creep, wear) demonstrate using analysis, test, data.

Structural Requirements & Compliance continued

- Fundamental Frequency
  - Maintain a minimum Frequency of 70 Hz
    (to decouple from ACD Fundamental Modes, which are around 50 Hz)
  - Comply by analysis using test correlated Finite Element Analysis (FEA) .
- Deformations
  - Determine gaps between tiles to accommodate TDA deformations under mechanical and thermal environments using test correlated FEA.
- Functional Performance
  - Operates within spec after exposure to environments
  - Comply by test

Mechanical & Thermal Environments

Summary of TDA Design Limit Loads				
CASE	***MECHANICAL LOADS***			***Acting On***
Vibro-Acoustic	Normal: 17 G	Lateral: 12 G	Single Axis	TDA
	Normal: 4.6 G	Lateral: 4.0 G	Combined	SIDE PANELS
	Normal: 6.5 G	Lateral: 4.0 G	Combined	TOP PANEL
Handling	10 LB in any direction			TDA
	THERMAL LOADS			
Extreme Cold Temperature	-40 C			ALL
Extreme Warm Temperature	+45 C			ALL

- **TDA and Panel Vibro-Acoustic Loads based on SEA responses from SAI-TM-2177. Tile Deformations determined under TDA and Panel combined Vibro-Acoustic Loads.**
- **Handling Loads: Limited to 10 LB at the blanket standoffs.**
- **Extreme Temperatures of –40 C and +45 C (Number of Cycles = 12)**
- **Operational Temperature of –21 C to +11 C (Number of Cycles = 30,000)**

Analysis Approach & Status

- FEA for individual Tiles to predict normal modes, frequencies, deformations, and flexure/interface reactions
- Detailed FEA of Flexures
  - for stiffness and strength sizing
- Correlate FEMs with test data
- Status
  - Correlations performed
  - Tile structural response predicted
  - Frequency and Strength Requirements satisfied
  - Tile Deformations predicted and Tile gaps submitted to science team

Tile FEA Overview

- Used for predicting:

1- Tile Normal Modes, and Frequencies,

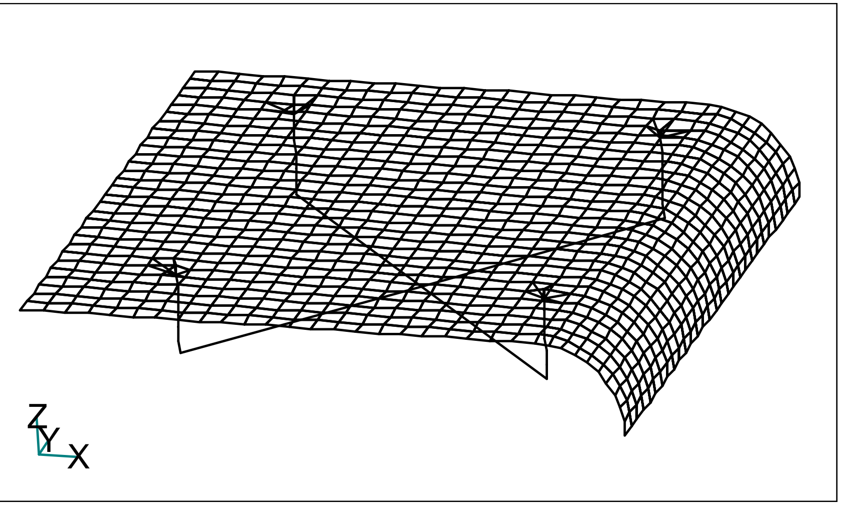
2- Tile Deformations and under Inertial and Thermal Loads

3- Flexure and Interface Reaction Forces, Tile Stresses under Mechanical and Thermal Loads

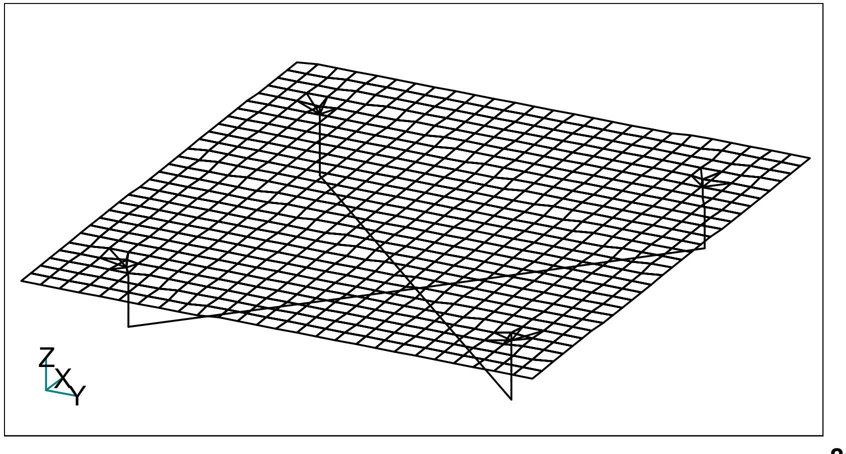
- Tile FEM validated by modeling the TDT configuration and correlating the vibe test and FEA results.

- Performed and passed FEM checks.

- 6 different FEMs are generated and used to simulate different flight tile designs.

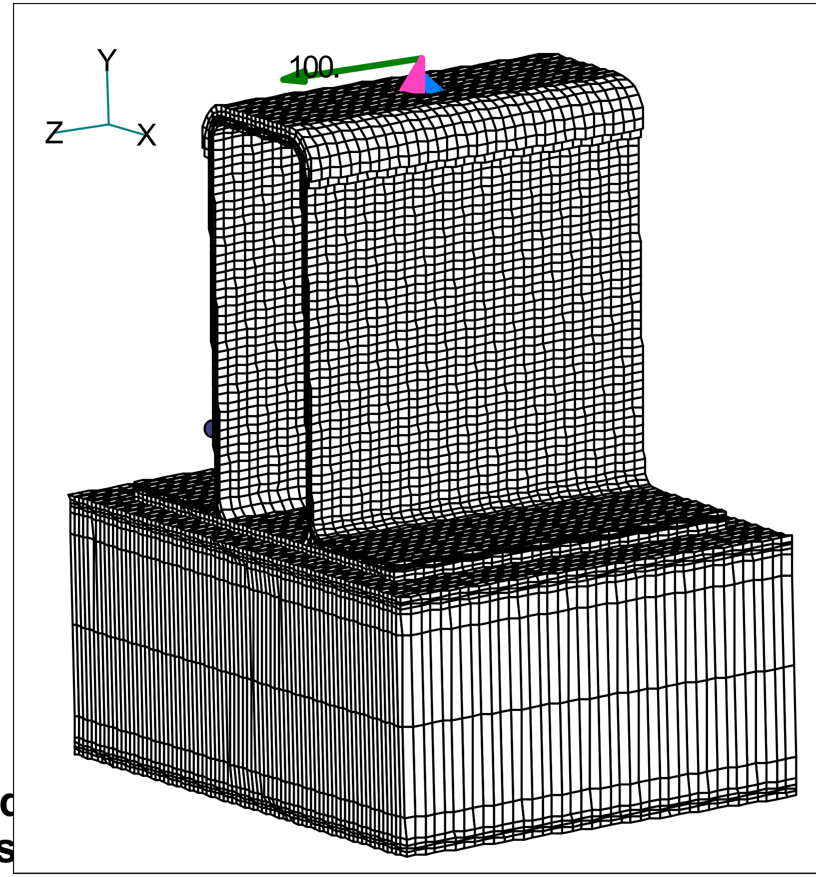


2 different Tile FEMs
(See through views and no Mass elements for clarity)

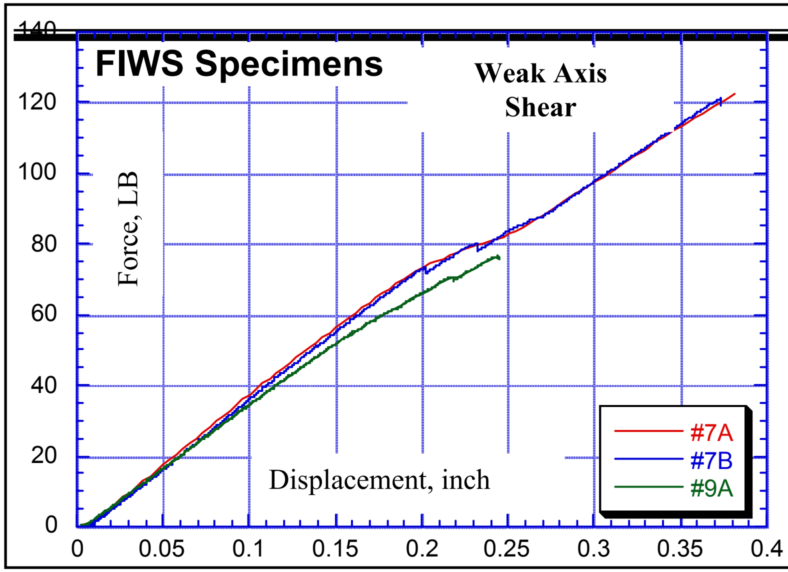


Flexure Detailed FEA
For Stiffness & Stress Analysis

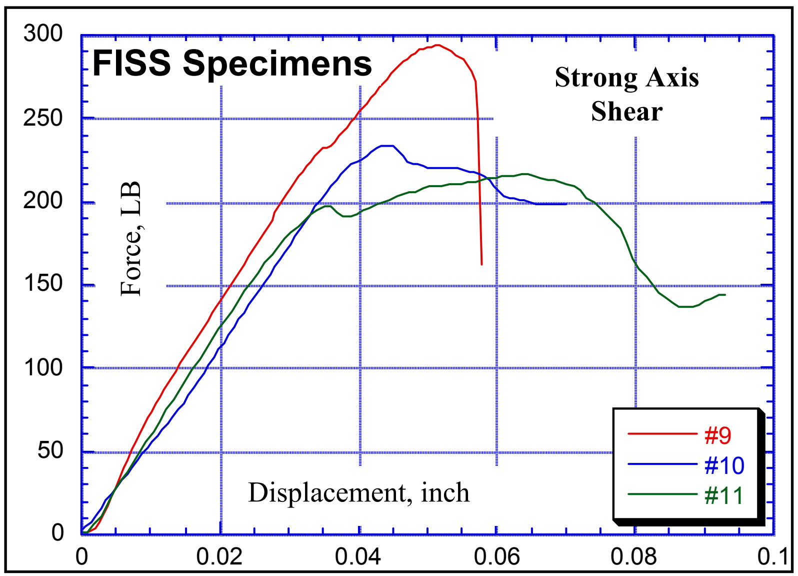
- **TDT Flexure FEM Properties:**
  T300 Plain Weave [0_3/45/0_3]
  Ex=Ey=7.8 msi, Gxy=1.12msi
  Blade Wall Thickness = 0.035”
  Flexure Height, H=1.6”
  Flexure Width, W= 1.5”
  Doubler Thickness= 0.040”
  Blade Spacing=0.55”
  Fillet Radii= 0.060”
- **Load Cases:**
  Strong Axis Shear (shown),
  Weak Axis Shear
  Tension/Compression
- **4 different flexure FEMs generated anc ... s.**
  They only differ in height and thicknes

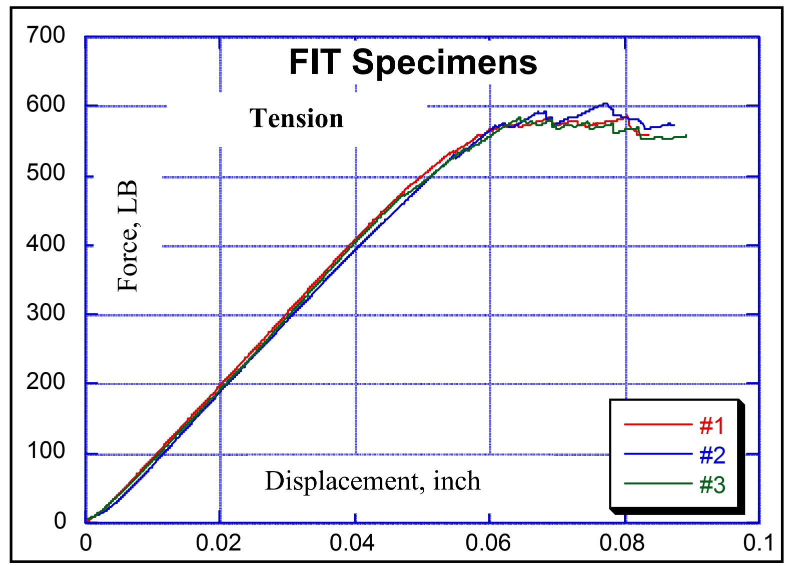


Flexure Pull Test Results



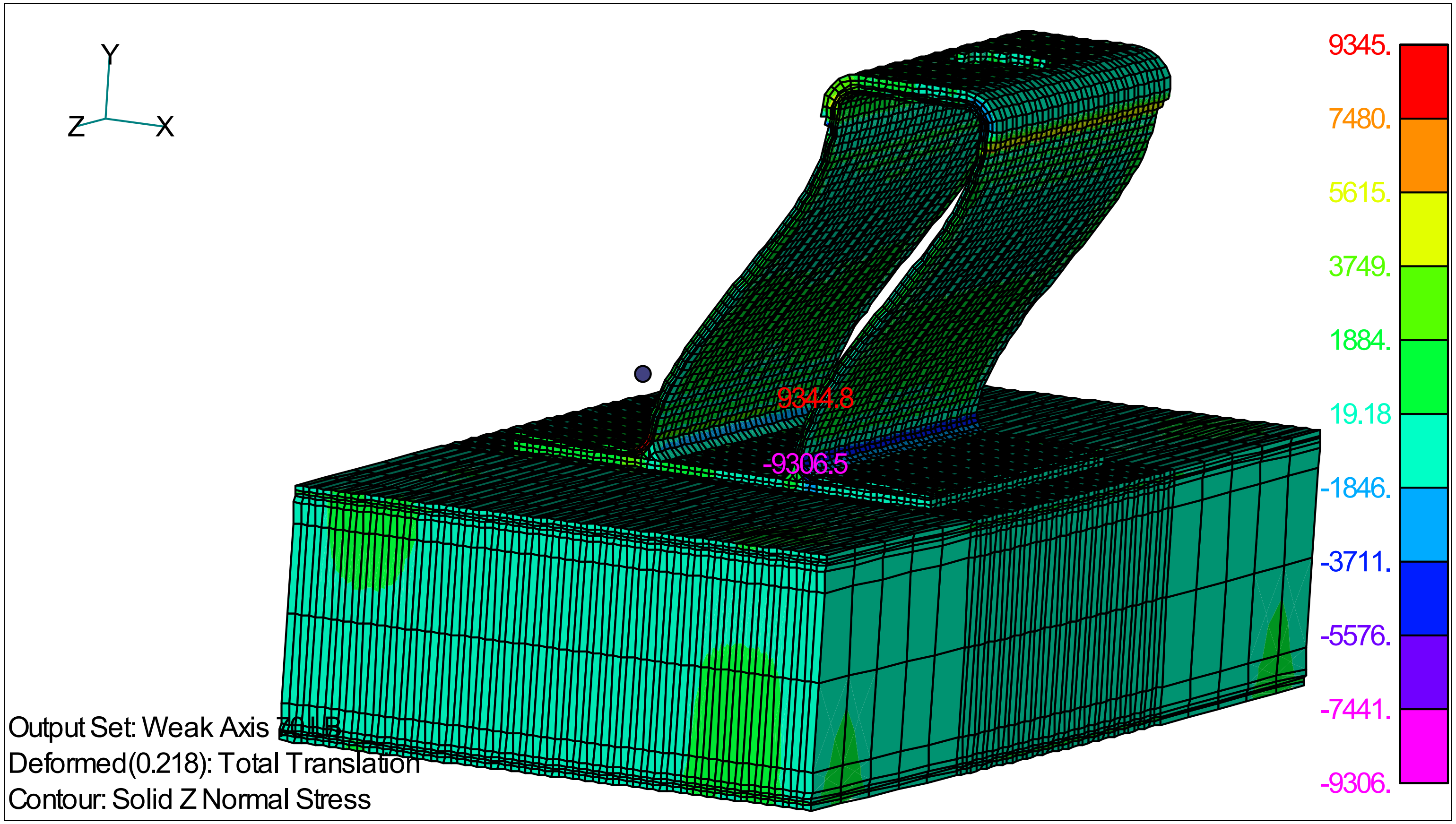
Flexure Pull Test Results Summary				
	Stiffness LB/in	Ult. Strength LB	Ult. Disp. inch	Failure Mode
Weak Axis Shear	340	70	0.206	Upper & Lower Flange delam
Strong Axis Shear	6250	200	0.032	Lower Flange delam
Tension	10600	550	0.052	Top Flange Bending
Comp-ression	54550	1000	0.018	Buckling & Core Crushing





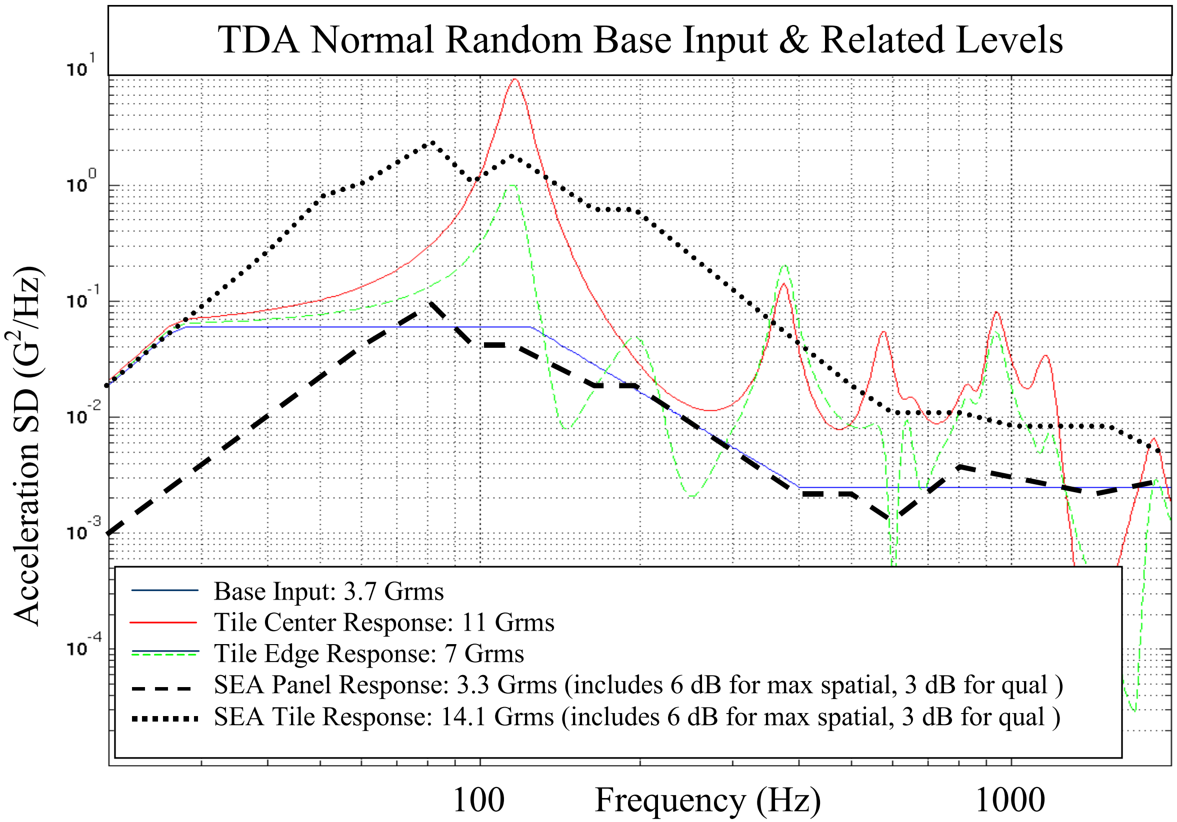
Flexure Stiffness & Strength Correlation under Weak Axis Shear

Under 70 LB weak Axis Shear:
Peel stresses exceed 9 ksi to cause failure in agreement with pull test results.
Stiffness=700/.218=320 Lb/inch (6 % less than measured)



Tile Detector Test
Normal Random Vibe Level

- SEA Panel and Tile results are used to derive TDT Random Vibe Levels. SEA results are scaled-up by 6 dB to envelope max spatial response and by 3 dB to reach qual levels.



- Normal Random Base input was selected to envelope the scaled SEA panel response. The envelope is expanded below the tile fundamental frequency to match the scaled TDA rigid SEA response.

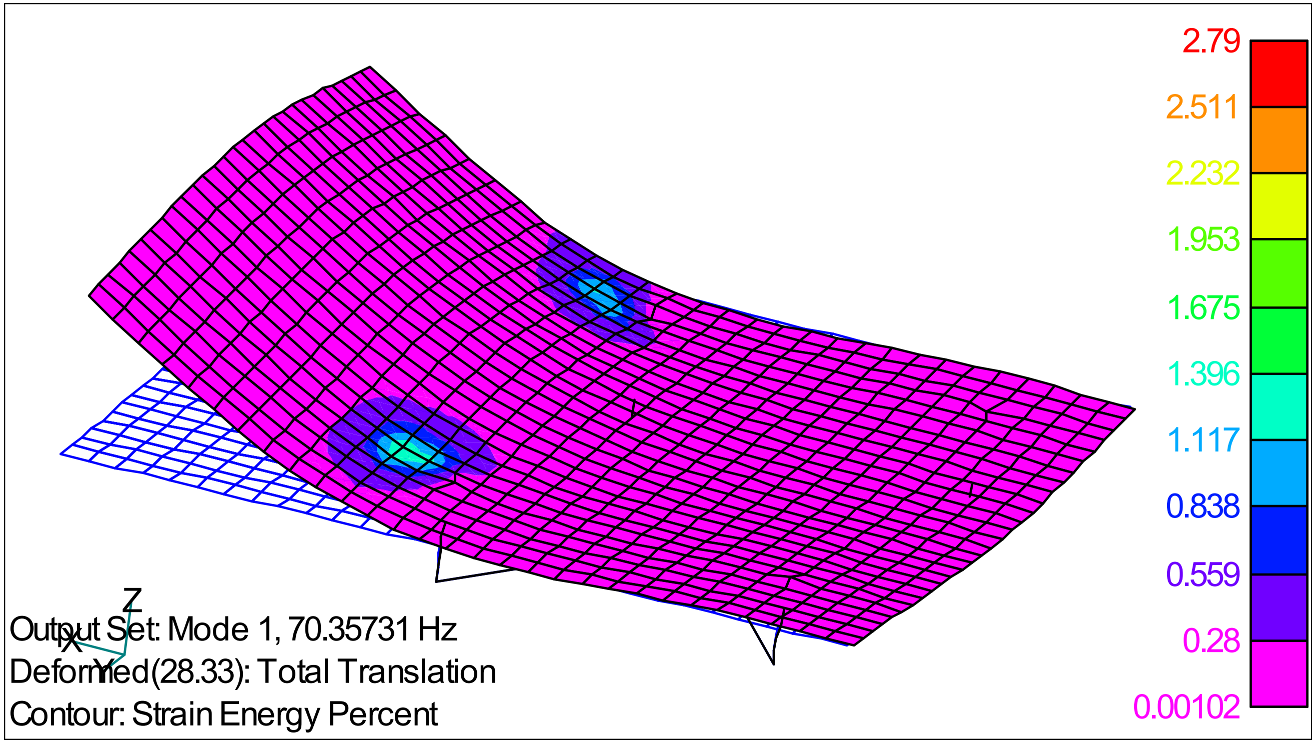
- Predicted and measured tile responses from random base-drive analysis roughly approximate the scaled SEA tile response, indicating that the selected base input is sufficiently high.

Tile Detector Vibe Test Results & Correlation Summary

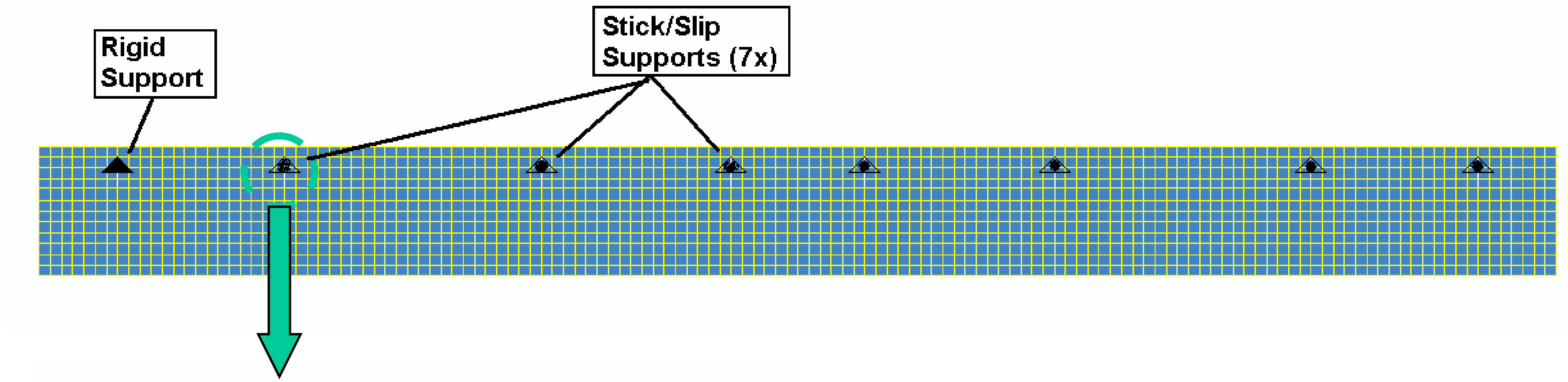
- Successfully passed Random Vibe and Sine Burst Tests (Normal 36 G and Lateral 22 G) without degradation of performance.
- FEM updated and tuned based on test results.
- Analysis & test Fundamental frequencies agree within 10%.
- A displacement uncertainty Factor of 1.5 is applied to FEA out-of-plane deflections to match the test results. This is potentially a conservative approach. LVDT data is being checked and the readings may turn out to be erroneously too high.
- The displacement uncertainty factor of 1.5 is also applied to the in-plane-deflection predictions, which are still well under test measurements . This is attributed to the over-sized holes in the flexures and the likelihood of slip at some of the friction interfaces. FEA results are not corrected for this but the excess in-pane motion measured is carried over into tile gap setting analysis.

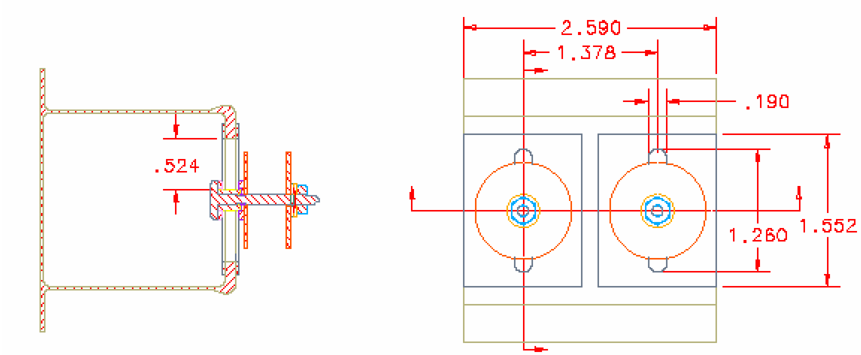
Tile Normal Modes

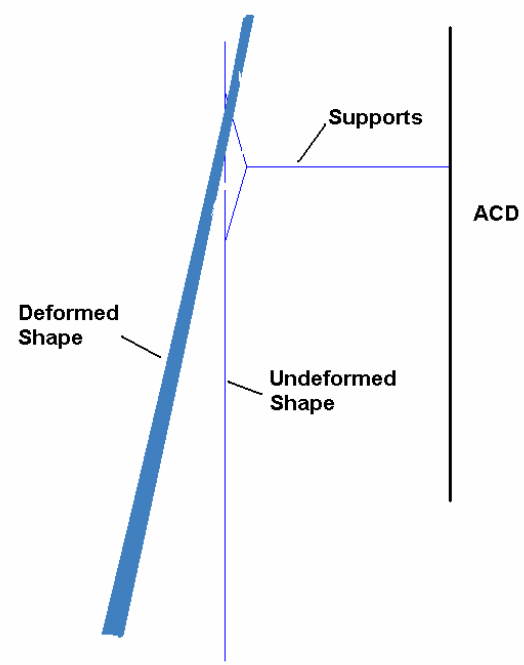
- Frequency requirement is met.
- Lowest Frequency is 70 Hz for the Side-4 Tiles (with the maximum overhang). Mode shape shown below.
- All other tiles have higher fundamental frequencies.



Bottom Tile FEA





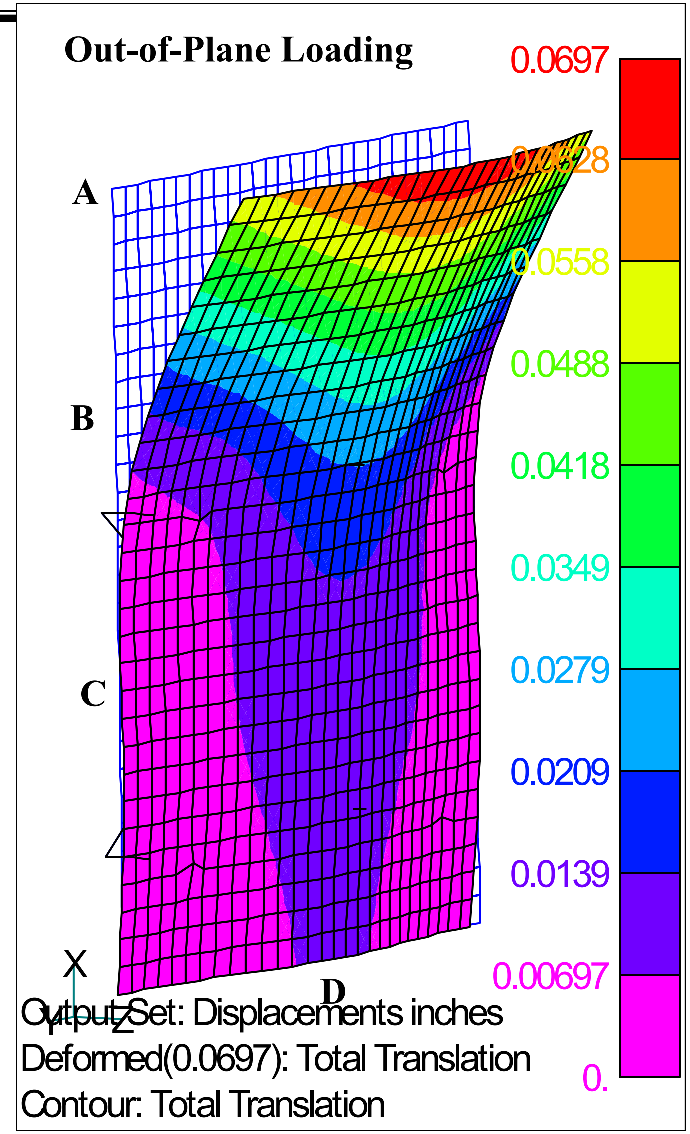


Bottom Tile Fundamental Mode is cantilevered twist as shown at a frequency of 72 Hz satisfying the requirement.

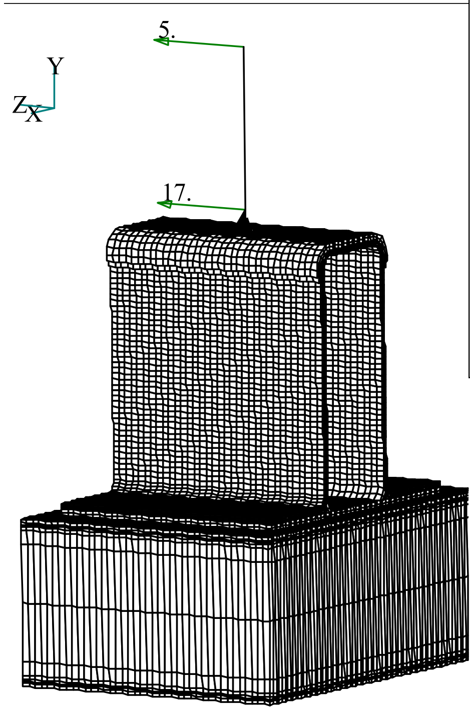
Side-4 Tile Deformations

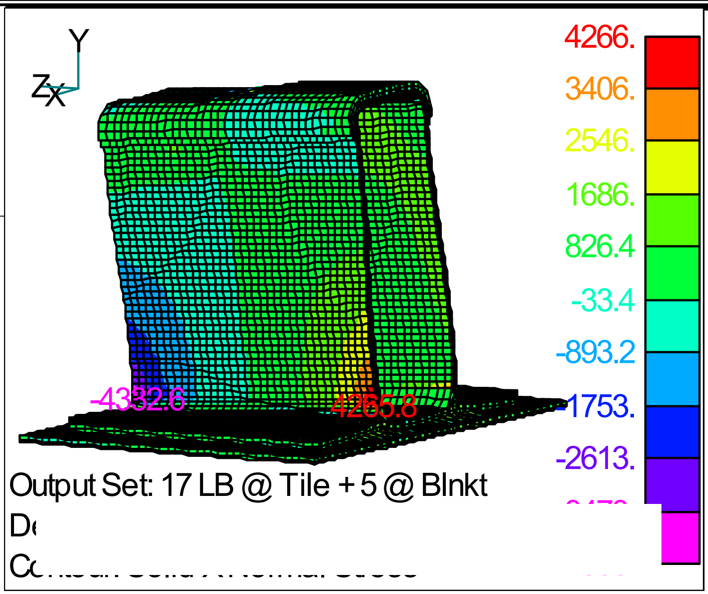
	Side-4 Tile Deformations			
	under Vibro-Acoustic Loading			
	normal	lateral		
Point	mm	mm		
A	1.3	0.1		
B	0.6	0.1		
C	0.1	0.1		
D	0.2	0.1		
	under Thermal Loading			
	-45 C	-25 C	+45 C	
Point	mm	mm	mm	
A				
B	-0.8	-0.6	0.2	
C	-0.8	-0.6	0.2	
D	-0.7	-0.5	0.2	

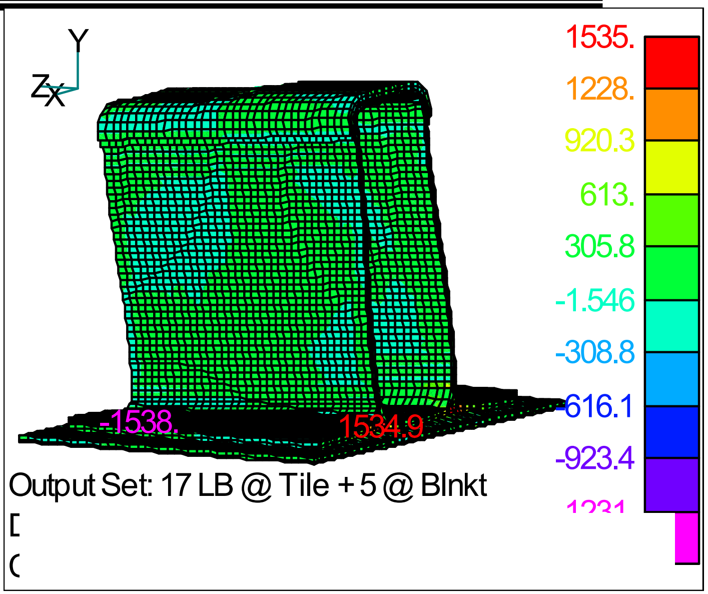
Tile motions caused by ACD Shell flexibility and deformations considered separately.

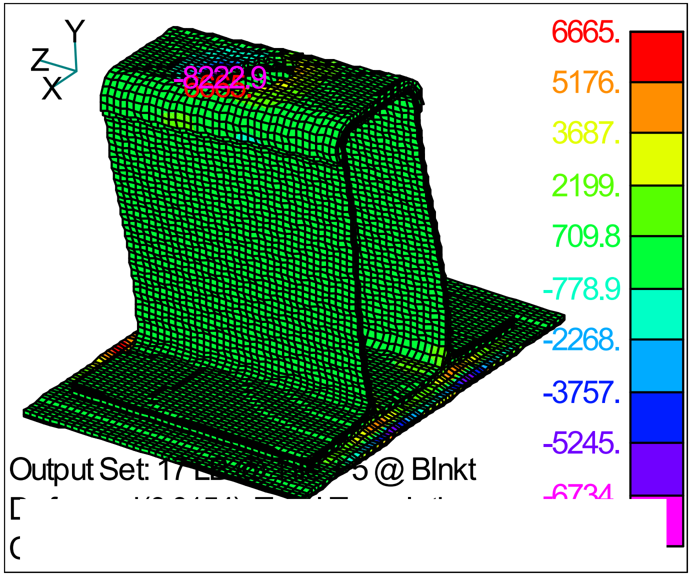


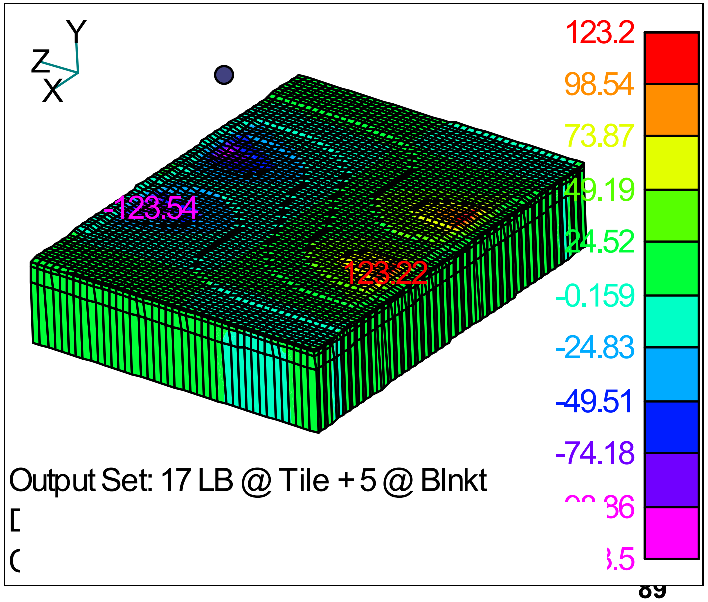
Flexure Sample Stress Analysis
Strong Axis Shear Loading











Summary of Margins of Safety (MS) for TDA and its Interfaces

	Part	Loading	Failure Mode	Applied Stress, psi	Allowable Stress, psi	Safety Factor	MS
1a	Tile	Vibro-Acoustic	Bending	660	4450	2.60	1.59
1b			Bearing	1960	6670	2.60	0.31
1c		Vibro-Acoustic+ Preload	Compression	3280 ultimate	4450	2.60	0.36
2a	Flexure & Interfaces	Thermally Induced motion of 0.035"	Lower Radii or Cap Delam	3300	8000	1.50	0.62
2b		Vibro-Acoustic (Strong Axis)	Lower Flange Delam	1540	8000	1.50	2.46
2c			Core Crushing	123	360	1.50	0.95
3	Tile Screw	Vibro-Acoustic	Tension+ Bending	139000 ultimate	160,000	1.40	0.15
4	Blanket Standoff	Handling	Bending	1590	16,500	2.60	2.99
Note:	Applied Stress is at the Limit Level unless otherwise indicated						

Conclusions

- **TDA Structural Analysis correlated with Pull and Vibration Tests performed. Correlated FEMs used in TDT normal modes, stress and deformation analyses.**
- **Fundamental Frequency Requirement (>70Hz) is met.**
- **All Strength Margins of Safety are positive for TDA parts and interfaces. Flexures are not prone to failure under sustained and cyclic thermal stresses based on conservative crack growth analysis and NDI (Non-Destructive Inspection) and/or Process Control for screening flexure laminate flaws.**
- **Enveloping tile deformations predicted under vibration and thermal loads for Tile gap sizing.**

Open Issues & Remaining Work

- **No open Issues.**
- **Provide structural analysis support for finalizing flight drawings, fabrication and I&T.**

GLAST Large Area Telescope:

AntiCoincidence Detector (ACD)

Critical Design Review (CDR)

BFA/BEA Mechanical Analysis

Kevin Dahya
Swales Aerospace
301-902-4584

NASA/Goddard Space Flight Center
January 7 & 8, 2003

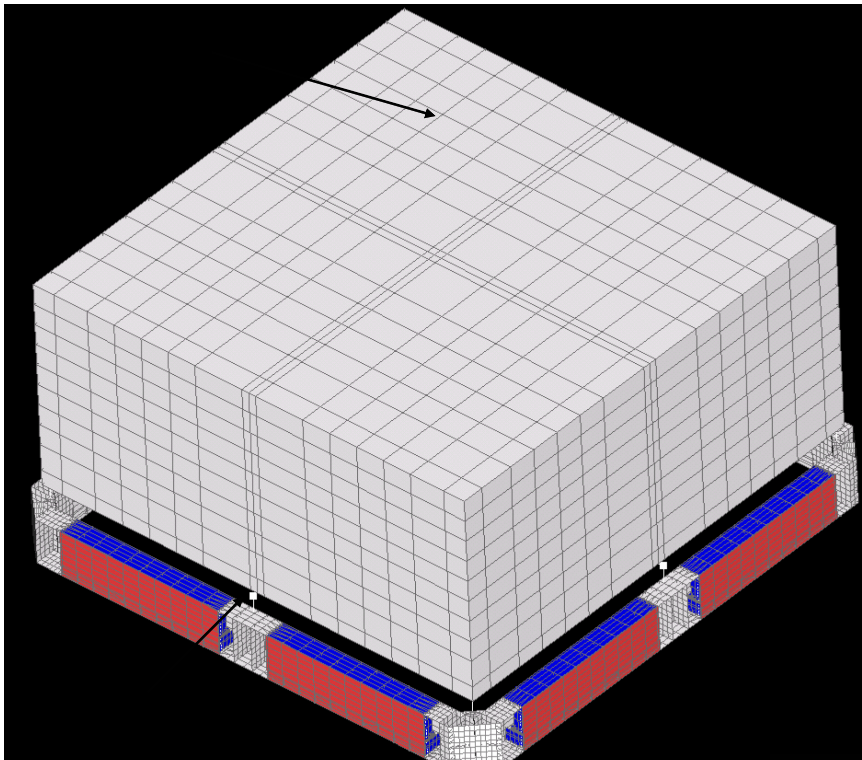
Base Electronics Assembly (BEA) Structural Analysis

Summary of BEA Design Limit Loads				
CASE	*MECHANICAL LOADS*			*COMPONENTS VALIDATED*
Lift-off	Thrust: 4.1 G	Lateral: 5.1 G	Combined	ALL
MECO	Thrust:6.8 G	Lateral: 0.2 G	Combined	ALL
Vibro-Acoustic	Thrust: 30 G	Lateral: 30 G	Single Axis	CHASSIS
	Thrust: 7 G	Lateral: 7 G	Single Axis	BFA
ACD Lift	Thrust: 1.6 G			BFA
THERMAL LOADS				
Extreme Cold Temperature	-40 C			ALL
Extreme Warm Temperature	+45 C			ALL

- **BEA structure composed of two components**
  - **Base Frame Assembly (BFA).**
    - **Support structure for TSA/TDA**
    - **Interfaces LAT at 8 locations (4 @ midspans, 4 @ corners).**
  - **Electronics Bay (Chassis).**
    - **Houses main electronic components.**
    - **Recesses into channel of BFA at 8 main locations.**
    - **Goal to meet fundamental frequency of greater than 80 Hz.**

FEM Description

TSA/TDA
and Blanket



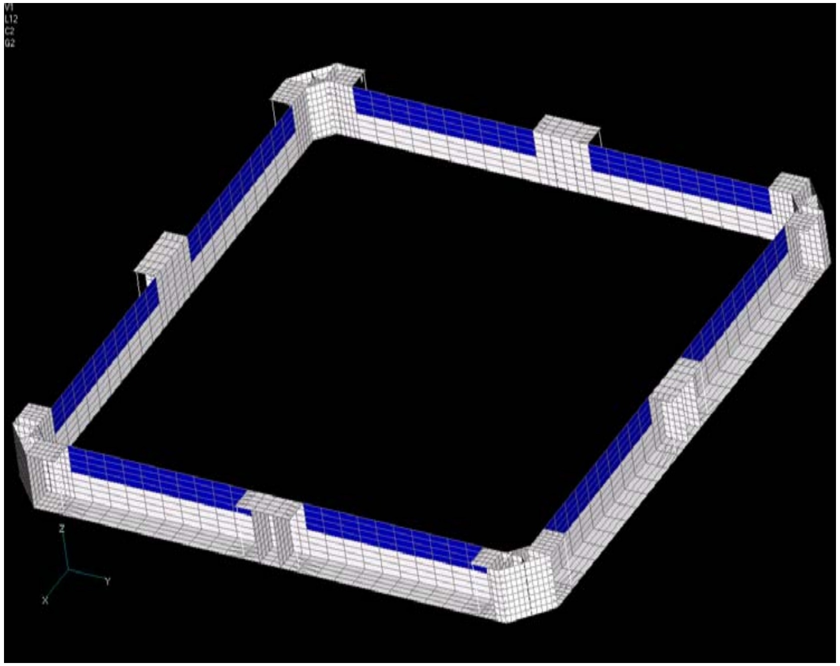
BEA

- TSA – Plate Elements
- TDA – Represented as non structural mass on TSA.
- Flexures – Bar elements with point masses.
- BEA – Plate Elements

ACD Weight Breakdown

	FEM Mass (Kg)	Mass Report Estimate (kg)
TSA/TDA/Blanket	200.45	193.0
Flexures	7.96	7.6
BEA	69.61	69.6
TOTAL	**278.02**	**270.2**

Base Frame Assembly (BFA)

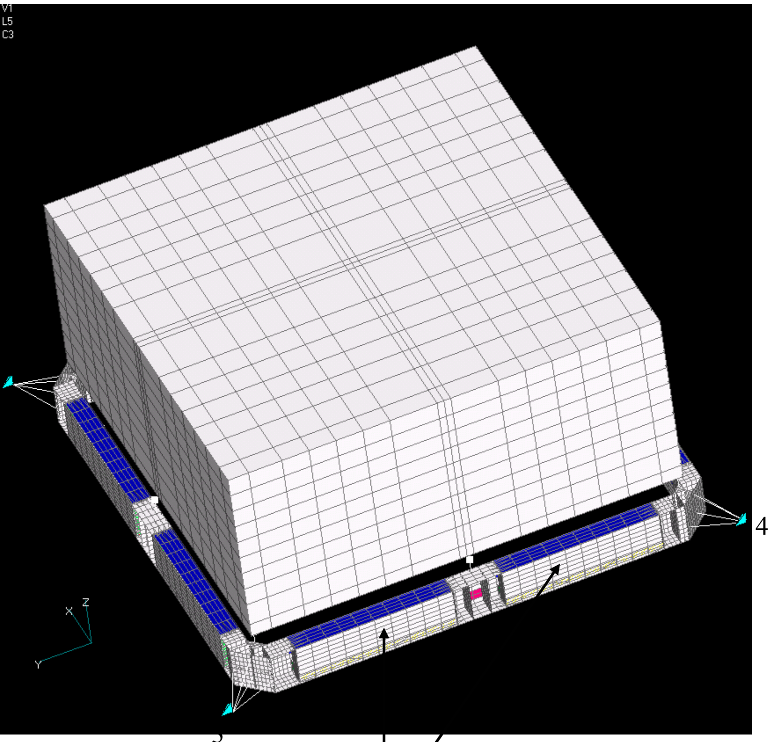


- BFA analyzed for 3 load cases
  - ACD Lift case. BFA coupled with TSA/TDA with 1.6 G load in thrust (-z) direction.
  - ACD Vibro-Acoustic case. BFA coupled with TSA/TDA with 10 G unidirectional loading.
  - ACD Design Limit Loads. BFA coupled with TSA/TDA and LAT for load cases specified below.

Axis	Liftoff/Airloads	MECO
	G	G
Thrust (Z)	4.1	6.8
Lateral	±5.1	±0.2

- All analysis performed with additional 10% weight contingency.

ACD Lift Case



Cover plates

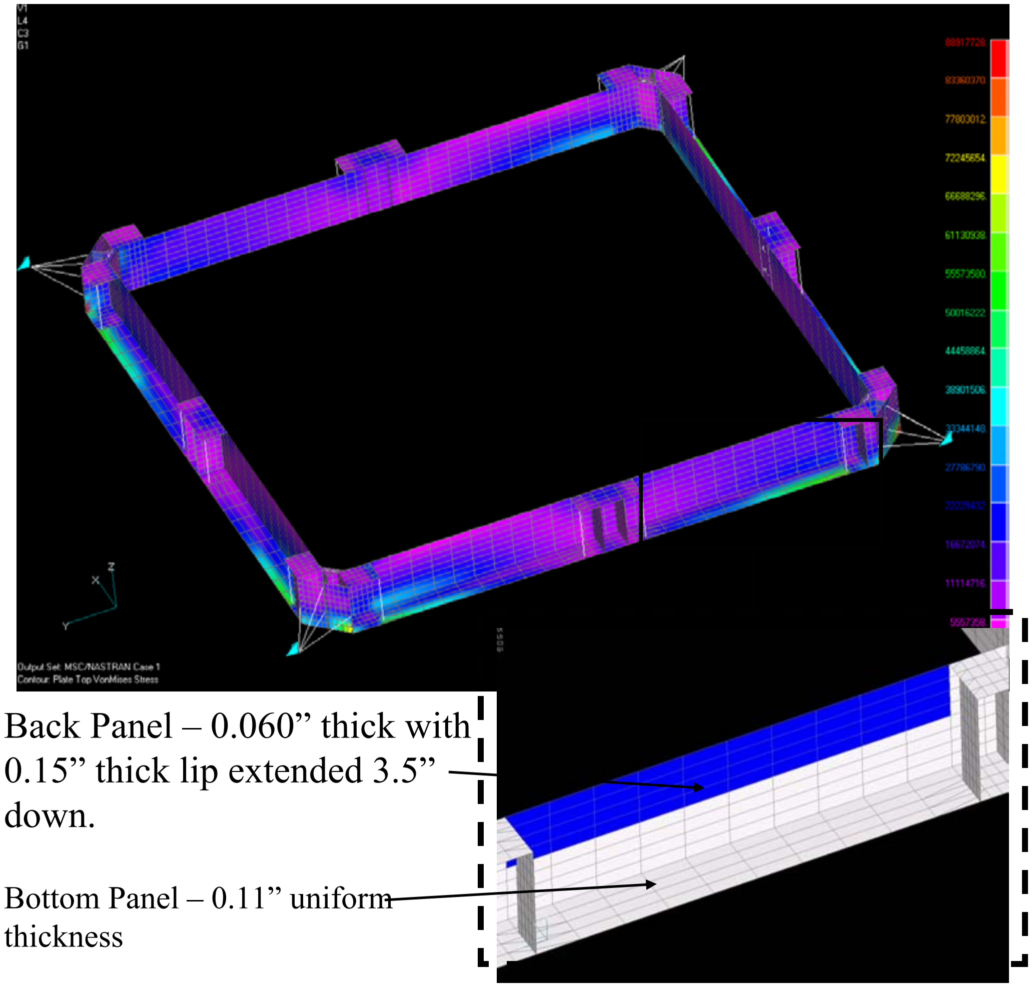
- Model constrained at 3 locations with 1 corner free.
  - Assumes two cables for lift and one for stability (worse case).
  - Nodes 2 and 4 used for lift and node 3 for stability.

Constraint Forces

Node	T3 - Thrust
2	2391
3	0.003
4	2391

- 1.6 G Body load applied in thrust direction.
- Chassis’ interfaced to BFA with minimum shear.
- Cover plates assumed non structural and removed during analysis.
- All analysis performed with additional 10% weight contingency.

ACD Lifting Loads Analysis



Back Panel – 0.060” thick with 0.15” thick lip extended 3.5” down.

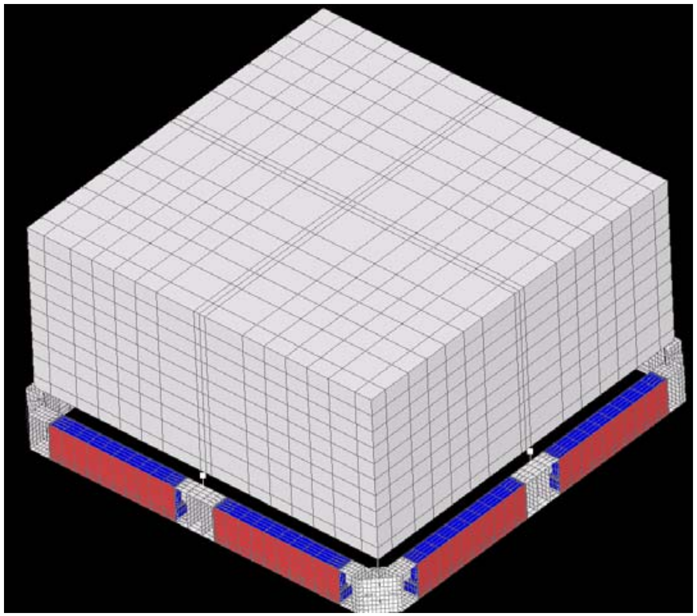
Bottom Panel – 0.11” uniform thickness

- Max Von Mises Stress

$$\sigma_{vm} = 88.92 Mpa = 12.90 ksi$$

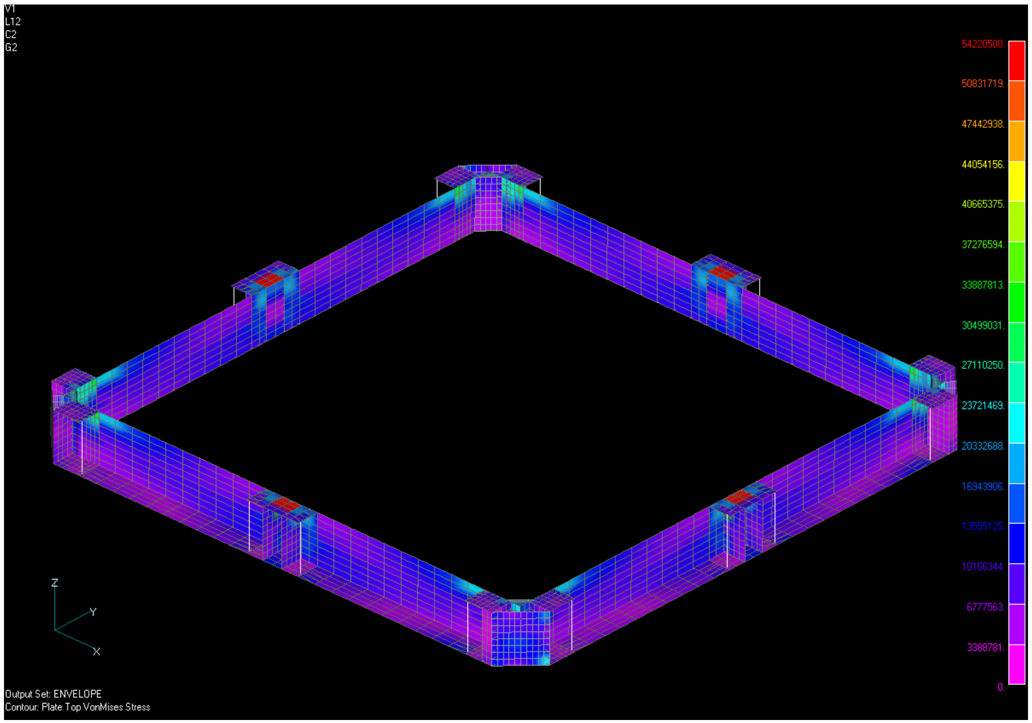
- Peak stresses localized on corner sections.
- Distribution of stress relatively low compared to material allowables (35 and 42 ksi, yield and ultimate)
- Buckling of back and bottom panels occur at low critical stress and have been analyzed in more detail.

ACD Vibro-Acoustic Case



- 7 G unidirectional load applied in x, y, z.
- Model fixed in translations at mid-spans and constrained in thrust direction at corners.
- Cover plates considered non-structural and removed during analysis.
- Max forces and stresses enveloped for all 3 cases.
- All analysis performed with additional 10% weight contingency.

ACD Vibro-Acoustic Loads Analysis

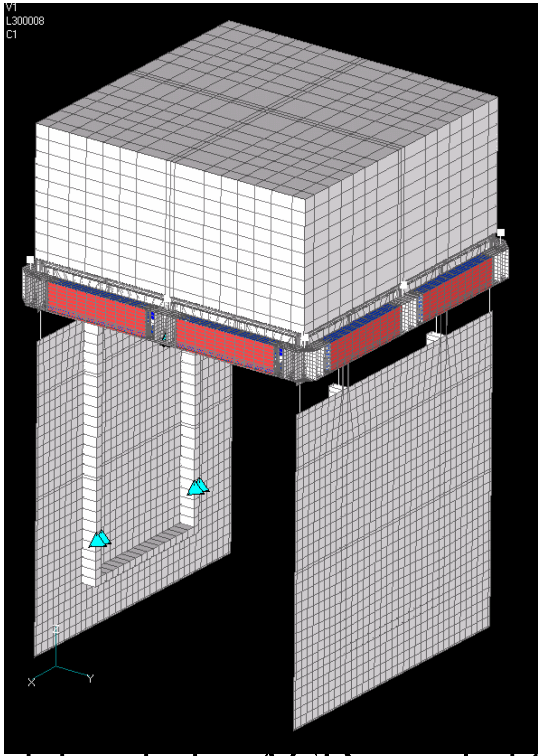


- Max Von Mises Stress

$$\sigma_{vm} = 54.22Mpa = 7.86ksi$$

- Peak stresses localized where flexures mount to BFA on corners and midspans.
- Distribution of stress relatively low compared to material allowables (35 and 42 ksi, yield and ultimate)
- Buckling of back and bottom panels occur at low critical stress and have been analyzed in more detail.

ACD Design Limit Loads Case

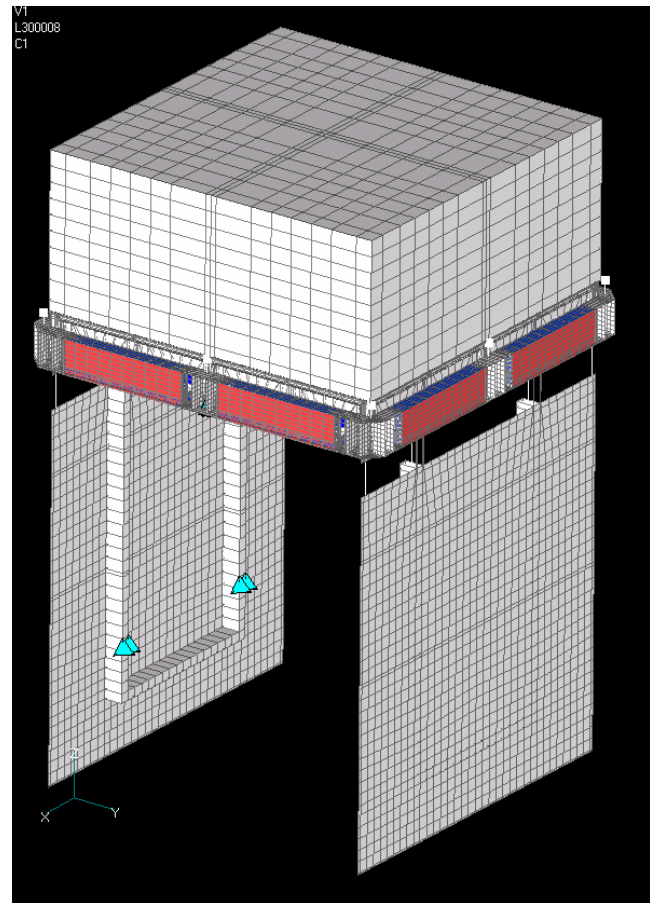


Model includes ACD coupled to LAT with radiator panels.

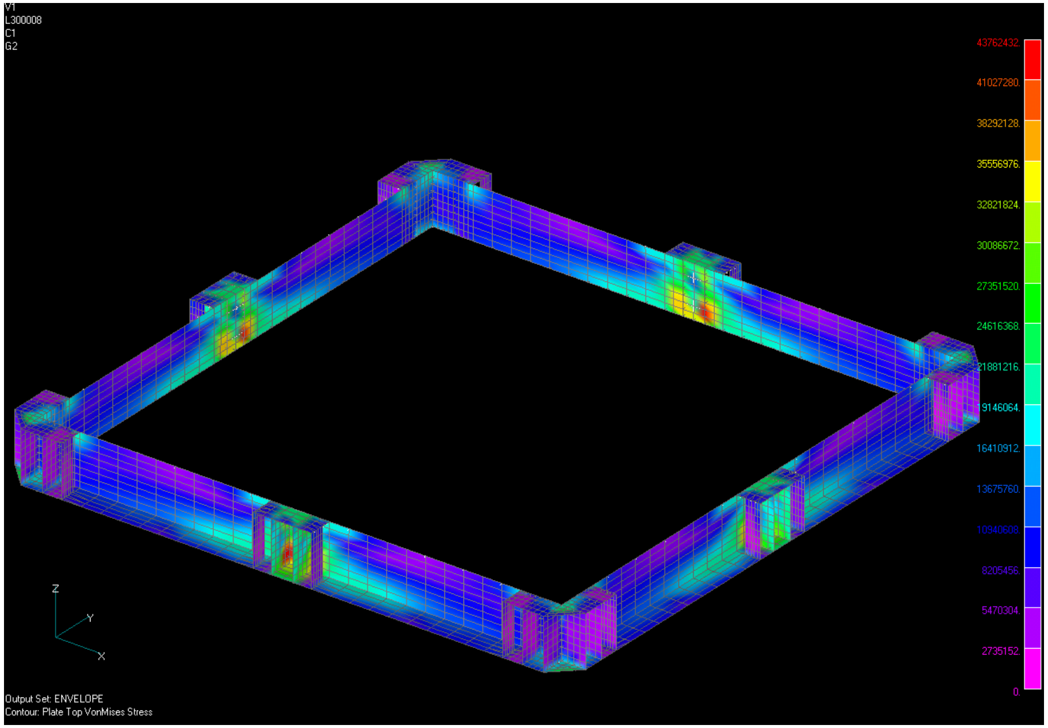
- •1G unidirectional plus 5.1G spiraled at 45° and 4.1G in thrust.
- •Model constrained on radiator panels and at midspans of BEA.
- •Max forces and stresses enveloped from all 12 load cases
- •Cover plates non-structural and removed during analysis.
- •All analysis performed with additional 10% weight contingency.

Design Limit Loads

- Case 1
  - 1.,0.,0.
- Case 2
  - 0.,1.,0.
- Case 3
  - 0.,0.,1.
- Case 4
  - 5.1.,0.,-4.1
- Case 5
  - 3.61,3.61,-4.1
- Case 6
  - 0.,5.1,-4.1
- Case 7
  - -3.61,3.61,-4.1
- Case 8
  - -5.1,0.,-4.1
- Case 9
  - -3.61,-3.61,-4.1
- Case 10
  - 0.,-5.1,-4.1
- Case 11
  - 3.61,-3.61,-4.1
- Case 12 (MECO)
  - 0.2,0.2,-6.8.



ACD Design Limit Loads Analysis



- Max Von Mises Stress

$$\sigma_{vm} = 43.76 Mpa = 6.35 ksi$$

- Stresses distributed from BEA/LAT interface locations.
- Distribution of stress relatively low compared to material allowables (35 and 42 ksi, yield and ultimate)
- Buckling of back panels occurs at low critical stress and have been analyzed in more detail.

Panel Buckling Analysis Methodology

- Running forces and shear forces seen by panel sections enveloped from FEM for lifting loads, vibro-acoustic loads, and design limit loads.
- Panel buckling benchmarked as flat sheet simply supported on 3 sides with compressive and shear loading.
- Hand analysis performed on benchmark case and correlated with FEA results to verify accuracy of FEM.
- Stability analysis performed on design with different stiffening configurations using FEA.

Applied Buckling Loads

- Back Panel worst case is ACD lift.

$$\sigma_{LD_{env}} = \frac{RunningForce}{thickness} = \frac{117904\,\frac{N}{m}}{0.0038m} = 31.03Mpa = 4.50ksi$$

$$\sigma_{SD_{env}} = \frac{RunningForce}{thickness} = \frac{3290\,\frac{N}{m}}{0.001524\,m} = 2.16Mpa = 313\,psi$$

$$\tau_{env} = \frac{ShearForce}{thickness} = \frac{10664\,\frac{N}{m}}{0.0038\,m} = 2.81\,Mpa = 407\,psi$$

- Bottom Panel worst case is ACD lift.

$$\sigma_{LD_{env}} = \frac{RunningForce}{thickness} = \frac{159502\,\frac{N}{m}}{0.0028m} = 57.09Mpa = 8.28ksi$$

$$\sigma_{SD_{env}} = \frac{RunningForce}{thickness} = \frac{21525\,\frac{N}{m}}{0.0028m} = 7.70Mpa = 1.12ksi$$

$$\tau_{env} = \frac{ShearForce}{thickness} = \frac{42500\,\frac{N}{m}}{0.0028\,m} = 15.21\,Mpa = 2.21\,ksi$$

Electronics Bay (Chassis) FEM

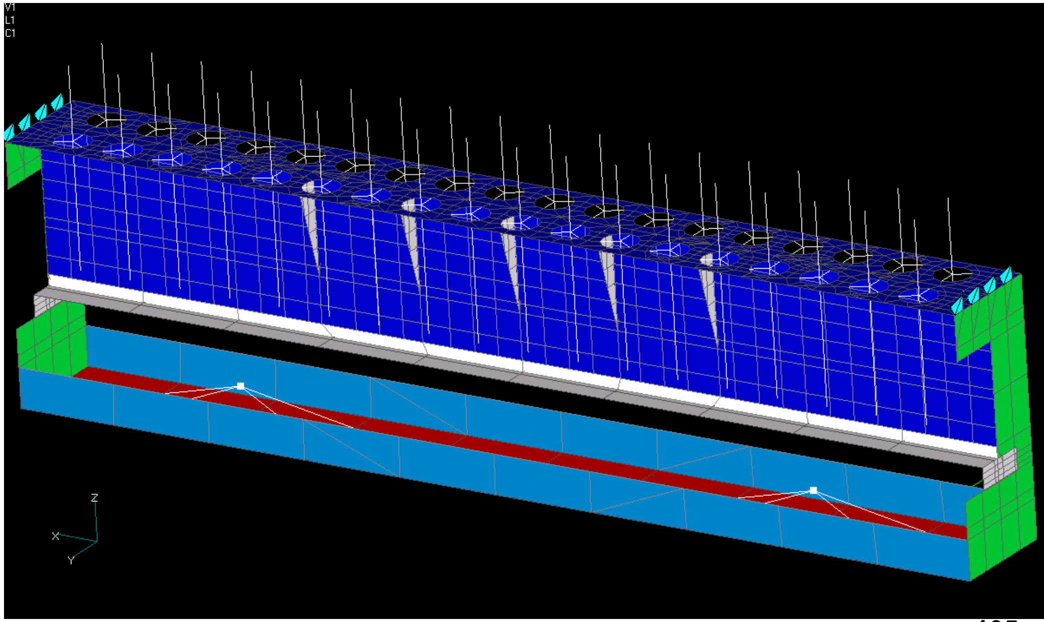
•Model contains assumed weights for packaged electronic components.

- –400 g / freecard (assumed point masses)
- –300 g / HVBS (assumed non structural mass)
- –30g/ pmt (Bar elements)
- –191 g / Power Distribution Module (assumed non structural mass)
  - •Ultem 1000 with density 1280 kg/m^3
  - •Module approx 8 in^3 (1.31e-4 m^3)
  - •Add 15% weight contingency

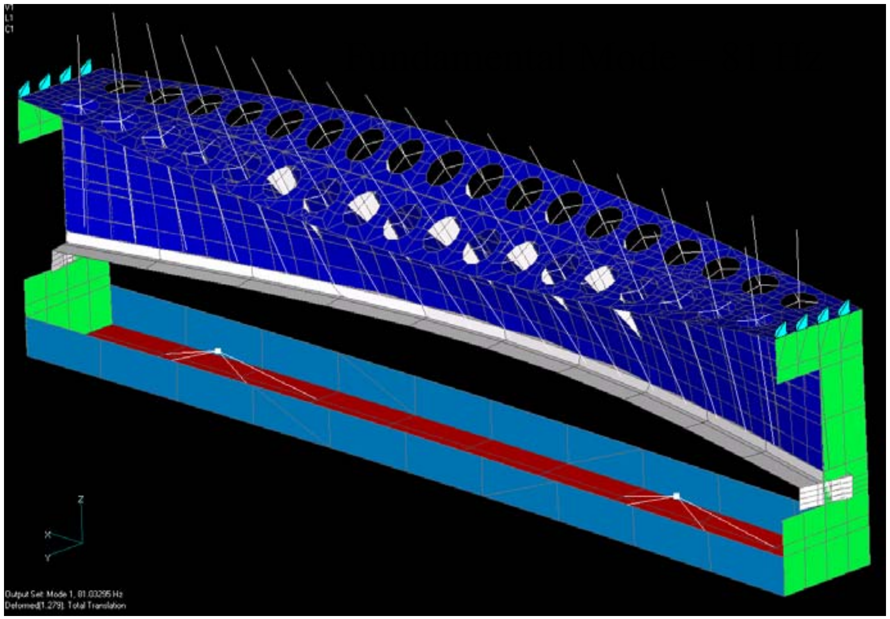
•Model constrained at 8 locations with minimum shear requirements.

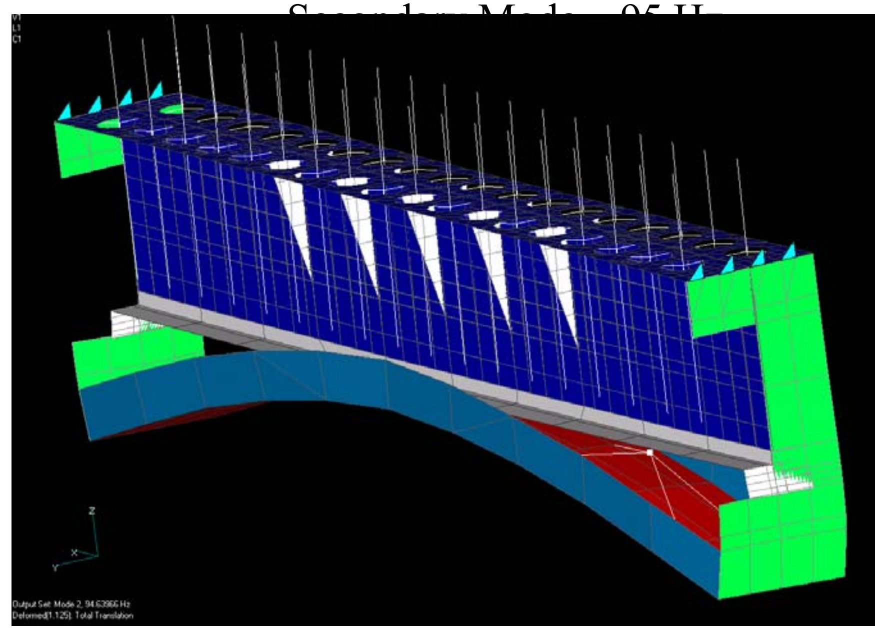
•All analysis performed with additional 10% weight contingency.

Description	Mass (kg)
Structural	3.21
Non Structural	1.05
Total	4.26



Chassis Normal Modes Analysis

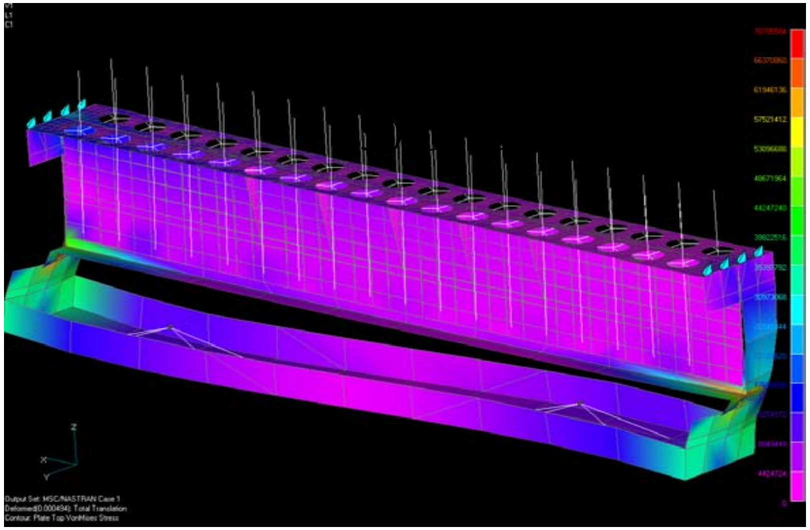


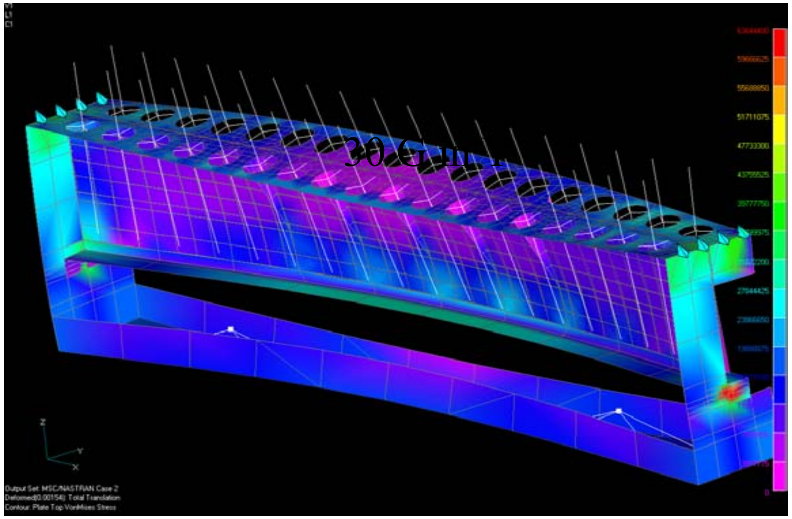


Mode	Fund Freq (Hz)
1	81
2	95
3	111
4	126
5	137

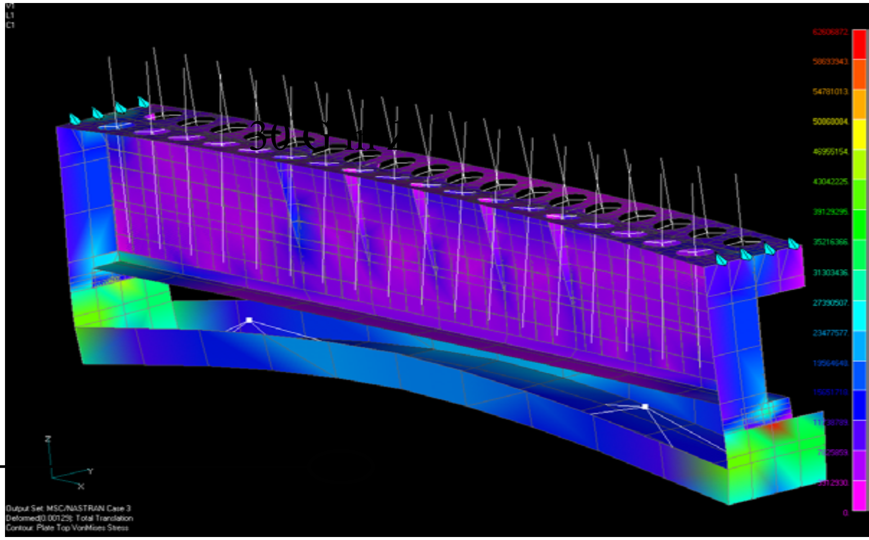
Electronics Chassis meets fundamental frequency requirement of greater than 80 Hz.

Chassis Static Analysis





Case	Stress	
	Mpa	*ksi*
30 G in X	70.8	10.27
30 G in Y	63.64	9.23
30 G in Z	62.61	9.08



Require 1.27 mm (0.050 in.) or less max displacement in z direction of chassis bottom. Currently at 1.27 mm displacement.

Margins of Safety Calculations

Material Strength Margin Calculations

Material: Aluminum 6061-T6

Yield Stress = 35 ksi

Ultimate Stress = 42 ksi

Yield Safety Factor = 2.0

Ultimate Safety Factor = 2.6

$$MS_y = \frac{\sigma_{yield}}{(YieldSafetyFactor)(\sigma_{app})} - 1$$

$$MS_u = \frac{\sigma_{ultimate}}{(UltimateSafetyFactor)(\sigma_{app})} - 1$$

Margin Calculations for Buckling

Buckling Safety Factor = 1.5

$$R_i = \frac{(\sigma_{app\,i})(BucklingSafetyFactor)}{\sigma_{all\,i}}$$

$$*\,MS = \left[\frac{2}{(R_{LD} + R_{SD} + \sqrt{(R_{LD} + R_{SD})^2 + 4R_\tau^{\,2}})} \right] - 1$$

* Ref. – MSFC Structures Manual, Vol. 1, 1975

Margin of Safety Summary

Base Frame Assembly and Chassis

BFA		Lift	Vibro-Acoustic	Design Limit Loads	Thermal
Material Strength					
Yield Stress	ksi	35	35	35	35
Ultimate Stress	ksi	42	42	42	42
Applied Stress	ksi	12.92	7.86	6.35	14.15
Margin of Safety Yield		***0.35***	***1.23***	***1.76***	***0.24***
Margin of Safety Ultimate		***0.25***	***1.06***	***1.54***	***0.14***

Chassis		
Material Strength		
Yield Stress	ksi	35
Ultimate Stress	ksi	42
Applied Stress	ksi	10.27
Margin of Safety Yield		***0.70***
Margin of Safety Ultimate		***0.57***

Fasteners

Chassis to BFA I/F		In Plane
Fasteners		
Yield Stress	ksi	95
Ultimate Stress	ksi	140
Applied Stress	ksi	10.69
Margin of Safety Yield		***3.44***
Margin of Safety Ultimate		***4.04***

Channel to Channel I/F		Lift	Vibro-Acoustic	Design Limit Loads
Fasteners				
Yield Stress	ksi	95	95	95
Ultimate Stress	ksi	140	140	140
Applied Stress	ksi	21.17	5.48	5.4
Margin of Safety Yield		***1.24***	***7.67***	***7.80***
Margin of Safety Ultimate		***1.54***	***8.83***	***8.97***
Shear Pins				
Ultimate Stress	ksi	85	85	85
Applied Stress	ksi	7.92	4.04	2.3
Margin of Safety Ultimate		***3.13***	***7.09***	***13.21***
Bearing Stress from Pins				
Yield Stress	ksi	35	35	35
Ultimate Stress	ksi	42	42	42
Applied Stress	ksi	15.52	7.91	4.52
Margin of Safety Yield		***0.13***	***1.21***	***2.87***
Margin of Safety Ultimate		***0.04***	***1.04***	***2.57***

Margin of Safety Summary - BFA Buckling

Back Panel

Back Panel		Lift	Vibro-Acoustic	Design Limit Loads	Thermal
Long Direction					
Allowable Stress	ksi	7.74	7.74	7.74	7.74
Applied Stress	ksi	4.5	2.93	2.3	4.083
Ratio		0.87	0.57	0.45	0.79
Short Direction					
Allowable Stress	ksi	5.11	5.11	5.11	5.11
Applied Stress	ksi	0.313	0.416	0.6643	0.249
Ratio		0.09	0.12	0.20	0.07
Shear					
Allowable Stress	ksi	5.33	5.33	5.33	5.33
Applied Stress	ksi	0.407	0.561	0.2428	0.906
Ratio		0.11	0.16	0.07	0.25
Margin of Safety		***0.02***	***0.38***	***0.54***	***0.07***

Bottom Panel

Bottom Panel Using (C)		Lift	Vibro-Acoustic	Design Limit Loads	Thermal
Long Direction					
Allowable Stress	ksi	15.14	15.14	15.14	15.14
Applied Stress	ksi	7.63	1.83	2.28	1.35
Ratio		0.76	0.18	0.23	0.13
Short Direction					
Allowable Stress	ksi	17.73	17.73	17.73	17.73
Applied Stress	ksi	0.99	1.53	1.88	1.21
Ratio		0.08	0.13	0.16	0.10
Shear					
Allowable Stress	ksi	70.09	70.09	70.09	70.09
Applied Stress	ksi	2.21	0.5139	0.3462	0.358
Ratio		0.05	0.01	0.01	0.01
Margin of Safety		***0.19***	***2.21***	***1.60***	***3.23***

Conclusions

- Base Frame Assembly
  - All margins positive for material strength using no test factors of 2.6/2.0 and for buckling analysis using factor of 1.5.
  - 7 G vibro-acoustic load preliminary. Awaiting SEA analysis.
- Electronics Bay Design
  - Meets strength and stability goals and requirements
    - Fundamental Mode > 80 Hz
    - Positive Margins with no test factors 2.6/2.0.
  - Currently at threshold of minimum displacement for bottom of chassis.
- FUTURE WORK
  - MGSE analysis (Lifting Brackets)

GLAST Large Area Telescope:

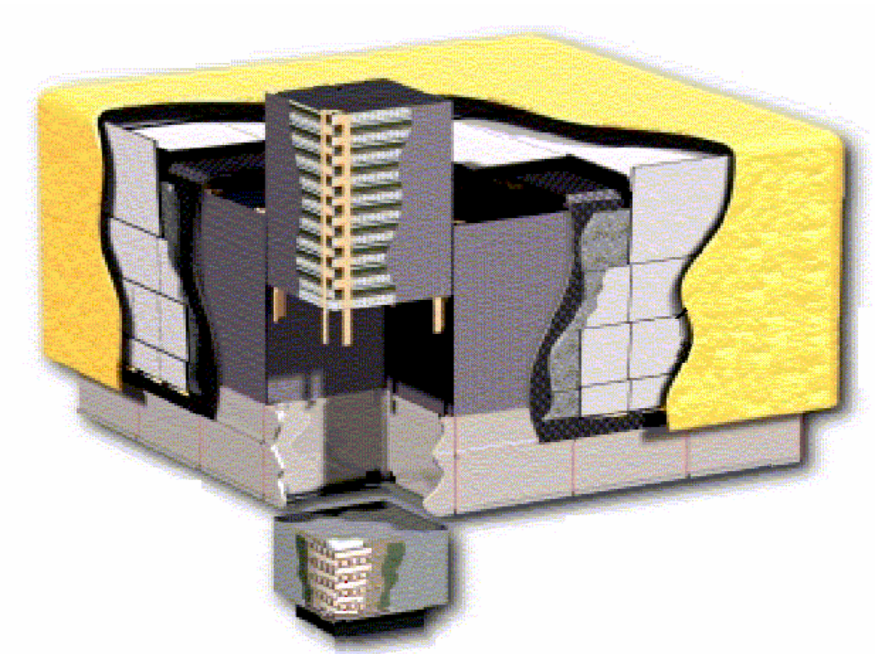
Anticoincidence Detector Thermal Subsystem Critical Design Review

Carlton V. Peters
Goddard Space Flight Center
Thermal Subsystem Engineer

Carlton.V.Peters@NASA.GOV

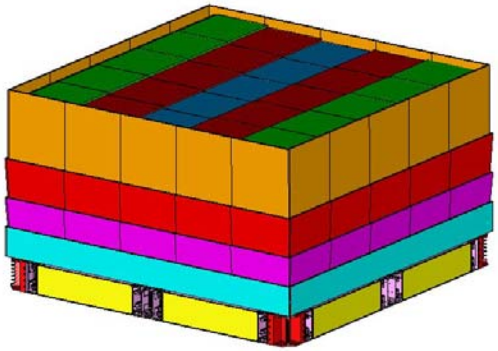
Contents

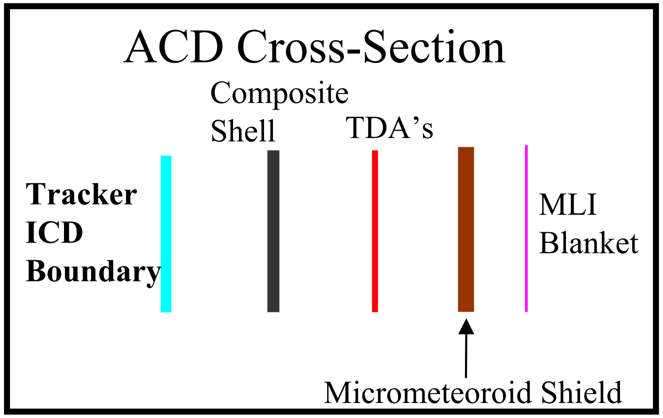
- ACD Design Configuration
- ACD Thermal Requirements
- ACD Power Dissipation
- Thermal Design Approach
- Thermal Analysis Conditions
- Thermal Analyses Assumptions
- Thermal Model Description
- Temperature Results
- Summary

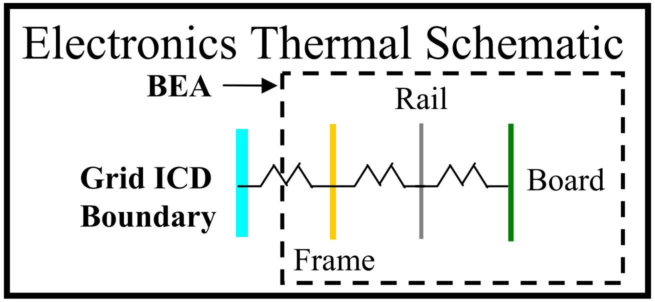


ACD Design Configuration

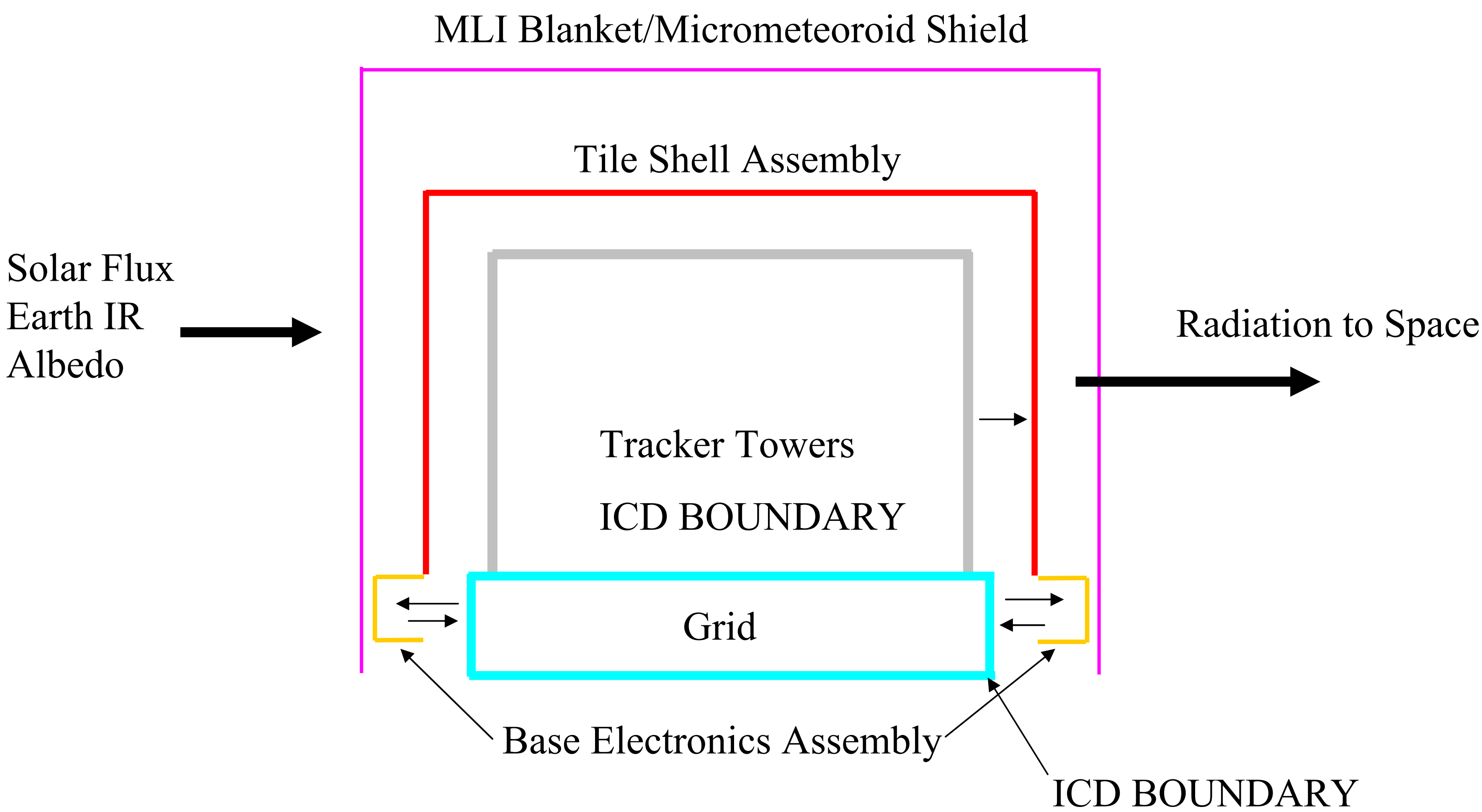
- Anticoincidence Detector covers all five external sides of the LAT
- External MLI Blanket has 3 mil Germanium Black Kapton outer layer and is composed of 14 blanket layers
- Blanket will be attached using a combination of standard blanket attachments such as Velcro, double sided tape and/or blanket buttons.
- Micrometeoroid shield includes approximately 3 cm of Solomide foam and Nextel layers
- Thin composite, low conductivity shell provides ACD structural support
- High emittance tracker exterior surfaces provide radiative path between tracker and ACD Shell interior
- Electronics Boards mounted to BEA Rail
- No dedicated radiator
- BEA mounted to grid at the 4 corners via corner fittings and at the center of each side by mid-span connectors







ACD Design Configuration



Changes since PDR

- ACD-LAT ICD Mechanical-Thermal-Electrical-LAT SS-000363-043 signed off.
- MLI Blanket outer layer has changed from 5 mil Silver Teflon to 3 mil Germanium Black Kapton
- LAT Tracker exterior surface change from low emissive surface to high emissive surface (black paint or anodize)
- ACD maximum power dissipation changed from 18 W to 14 W

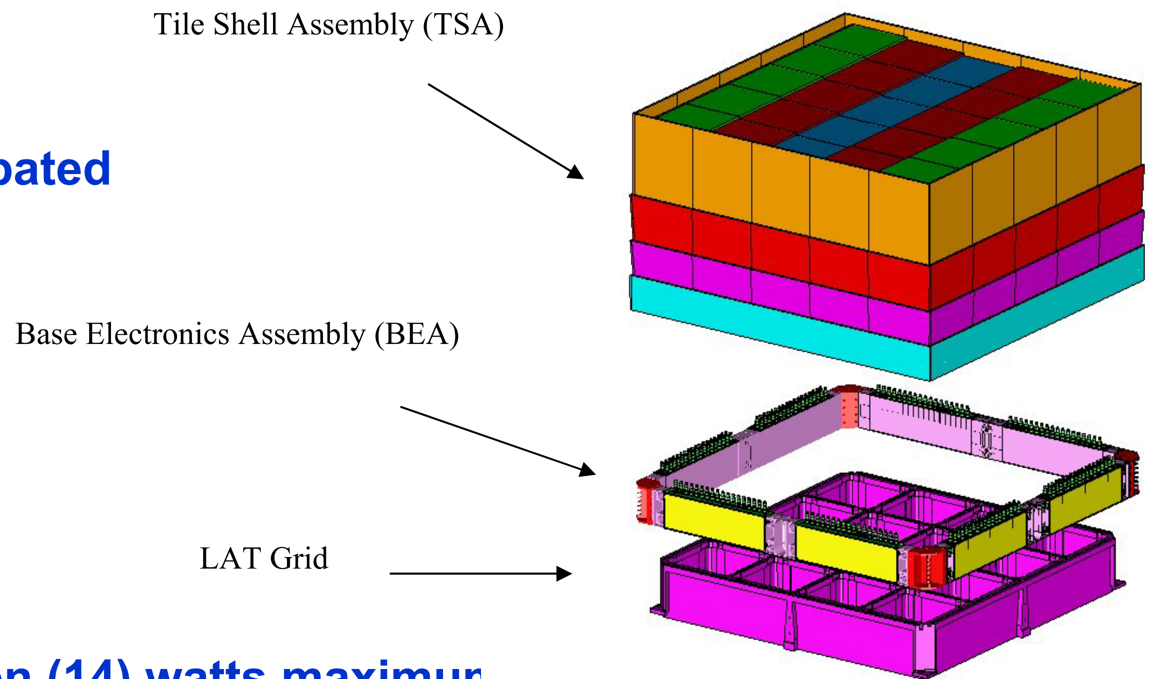
ACD Thermal Requirements

- ACD TDA
  - Requirement applicable at TDA external surface
  - Survival requirement driven by optical epoxy adhesive (Bicron B-600)
  - Survival limit of 45 ^{o}C cannot be exceeded in test
- Electronics Interface
  - Requirement applicable at board interface, the BEA Rail
  - Survival requirement driven by the PMT’s

	BEA	TDA
Operational min/max	-20/35	-30/35
Qualification min/max	-30/45	-35/45
Survival min/max	-40/45	-60/45

- Temperatures are in ^{o}C

ACD Power Dissipation



Tile Detector Assembly

- No power dissipated

- **Electronics**
  - A total of Fourteen (14) watts maximum dissipated at 12 board locations
  - 1.2 watts per board
  - 4 boards located on both ± Y sides and 2 boards located on ± X sides
  - Board Analysis needs to be completed

Thermal Design Approach

Tile Detector Assembly

- Passive thermal design approach
- The following ACD characteristics argue for a thermal design approach based on local thermal environment considerations for any of the five sides:
    - LAT Point anywhere anytime viewing requirements
    - TDA's located on all five ACD exterior sides
    - Poor lateral thermal conduction characteristics through the ACD TDA structural support (low conductivity composite shell)
    - No dedicated radiator

Electronics Board Interface

- Passive thermal design approach without survival heaters
- Electronics board interface temperatures are driven by the grid cold sink boundary temperature since heat transfer from the board interface to the grid is through a series conduction heat transfer path.

Thermal Analysis Conditions

Hot case

- For any ACD exterior side, occurs when the solar vector is normal to the ACD side with maximum earth infrared and albedo energy input.
  - 25 ^{o}C Tracker effective radiation sink environment
- And for the electronics when specified grid ICD boundary temperature is maximum
  - Operational Grid Boundary = 20 ^{o}C
  - Survival Grid Boundary = 30 ^{o}C

Cold case

- For any ACD exterior side, occurs when an ACD side is shadowed from direct solar input and pointed in the zenith direction where earth infrared and reflected albedo solar input is minimum.
  - -10 ^{o}C Tracker effective radiation sink environment
- And for the electronics when specified grid ICD boundary temperature is minimum
  - Operational Grid Boundary = -10 ^{o}C
  - Survival Grid Boundary = -15 ^{o}C

Thermal Analyses Assumptions

Orbital Analysis

- **Thermal Environment Design Parameters**

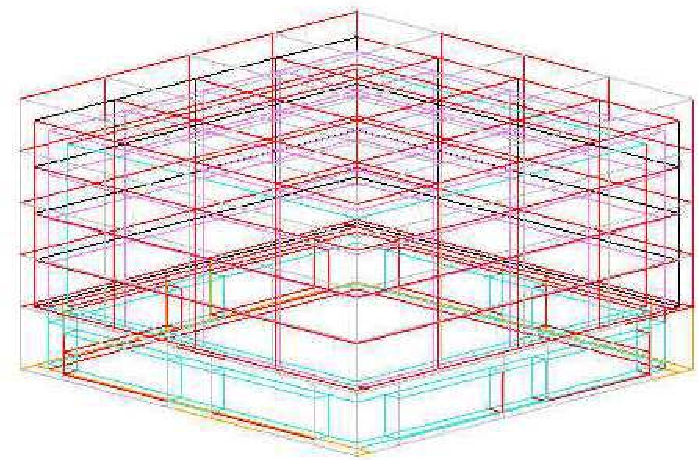
	COLD	HOT	UNITS
EARTH IR	66 208	84 265	Btu / Hr sq. ft Watts/ sq. meter
SOLAR CONSTANT	408 1287	450 1420	Btu / Hr sq. ft Watts/ sq. meter
SOLAR ALBEDO	0.25	0.40	Dimensionless

- **Optical properties**

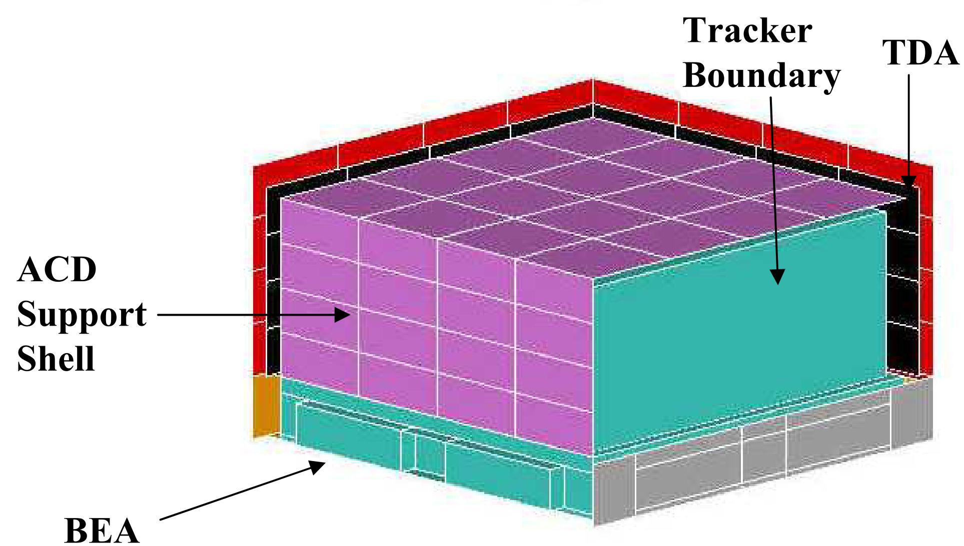
TSS Optics Name	Description	Emissivity (BOL)	Absorptivity (BOL)	Emissivity (EOL)	Absorptivity (EOL)
3_mil_Kapton	Interior Closeouts	0.79	*	0.75	*
3 mil Ge Black Kapton	Exterior MLI Blanket	0.82	0.51	0.78	0.55
Black Anodize	Tracker Towers	0.82	*	0.78	*
Black Anodize	Grid Exterior and BEA	0.82	*	0.78	*
m46J/RS-3	ACD Shell	0.93	*	0.90	*

Thermal Model Description

- **TSS Geometric Math Model**
  - TSS Surface Model used to calculate view factors and orbital fluxes
  - 90 Surfaces with 484 active nodes
  - Output: RADKS and heat rates



- **SINDA Thermal Math Model**
  - 512 total nodes
  - Input: RADKS and heat rates



Thermal Design Results

Description	Cold Operating Temperature	Hot Operating Temperature	Cold Survival Temperature	Hot Survival Temperature	Operating Temperature Limits	Survival Temperature Limits
Grid Boundary	-10	20	-15	30	-	-
Trackers Boundary	-10	25	-20	30	-	-
ACD Composite Shell	-13	26	-23	31	-	-
Tile Detector Assembly	-16	27	-25	32	-30 to 35	-60 to 45
BEA ±X Rail	-10	24	-16	31	-20 to 35	-40 to 45
BEA ±Y Rail	-9	24	-16	29	-20 to 35	-40 to 45

- **All temperatures in ºC**
- **Predictions shown are raw predicts and margin does not reflect 5 ºC analytical uncertainty**

Summary

- Thermal design approach bounds worst case hot and cold possibilities
- TDA temperature requirements satisfied in design, external MLI effective emittance needs to be less than 0.03
- Effective emittance of 0.03 or less can be achieved with 14 blanket layers
- Tracker exterior surfaces are high emittance in order to couple TDA's to Tracker temperatures rather than MLI temperatures
- ICD boundary conditions are the thermal design drivers
- Electronic Board Thermal Analysis must be completed

Thermal Design Results (Backup)

Description	Cold Operating Temperature	Hot Operating Temperature	Cold Survival Temperature	Hot Survival Temperature	Operating Temperature Limits	Survival Temperature Limits
Grid Boundary	-10	20	-15	30	-	-
Trackers Boundary	-10	25	-20	30	-	-
ACD Composite Shell	**-22**	27	**-31**	31	-	-
Tile Detector Assembly	**-24**	28	**-33**	32	-30 to 35	-60 to 45
BEA ±X Rail	-10	24	-16	31	-20 to 35	-40 to 45
BEA ±Y Rail	-9	23	-16	29	-20 to 35	-40 to 45

- **All temperatures in ºC**
- **Results shown are for low emissive Tracker surface**
- **Predictions shown are raw predicts and margin does not reflect 5 ºC analytical uncertainty**

GLAST Large Area Telescope:

AntiCoincidence Detector (ACD)

Critical Design Review (CDR)

ACD Manufacturing

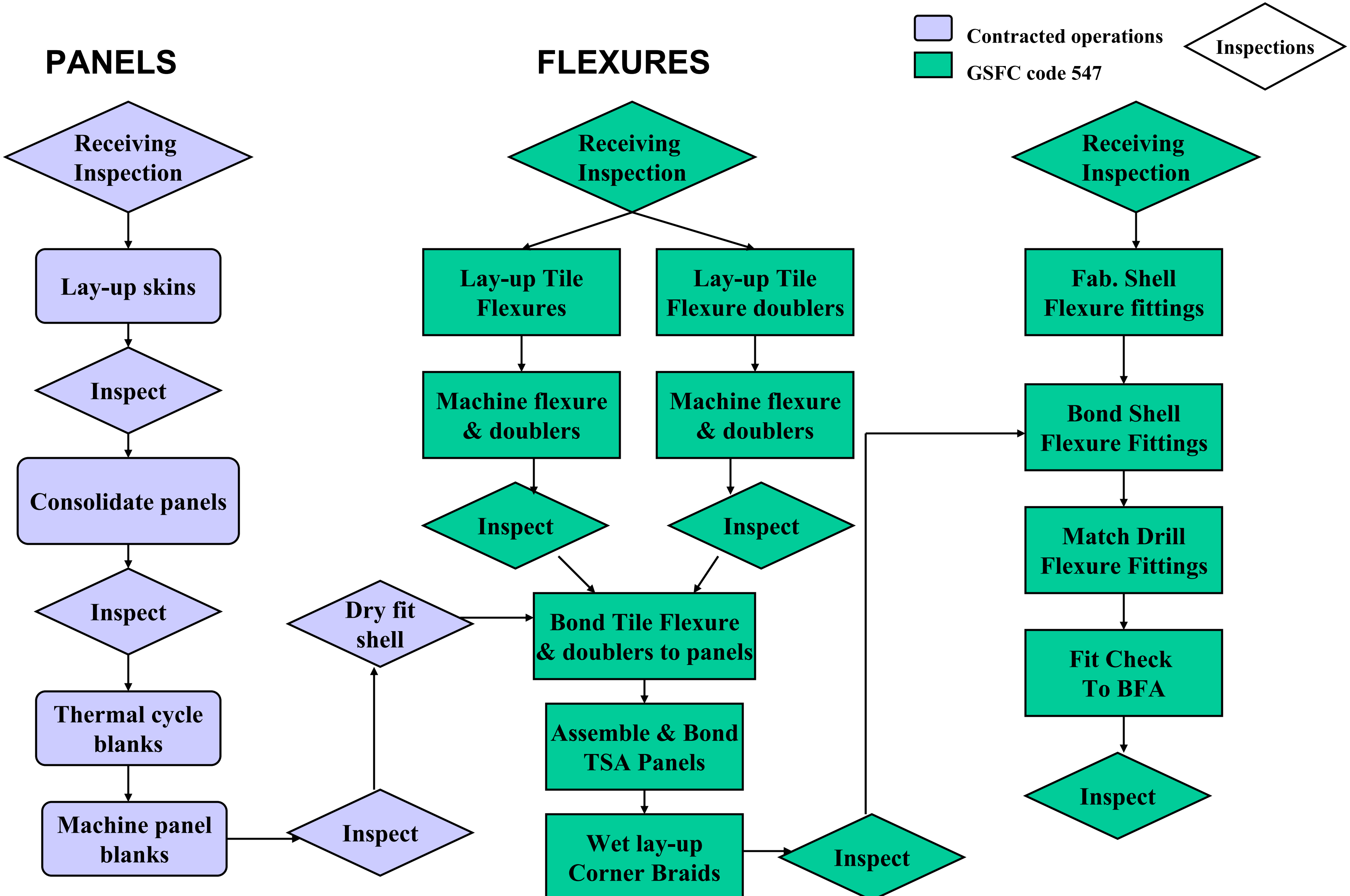
Russell Rowles
Senior Composite Technician
301-286-9660

NASA/Goddard Space Flight Center
January 7 & 8, 2003

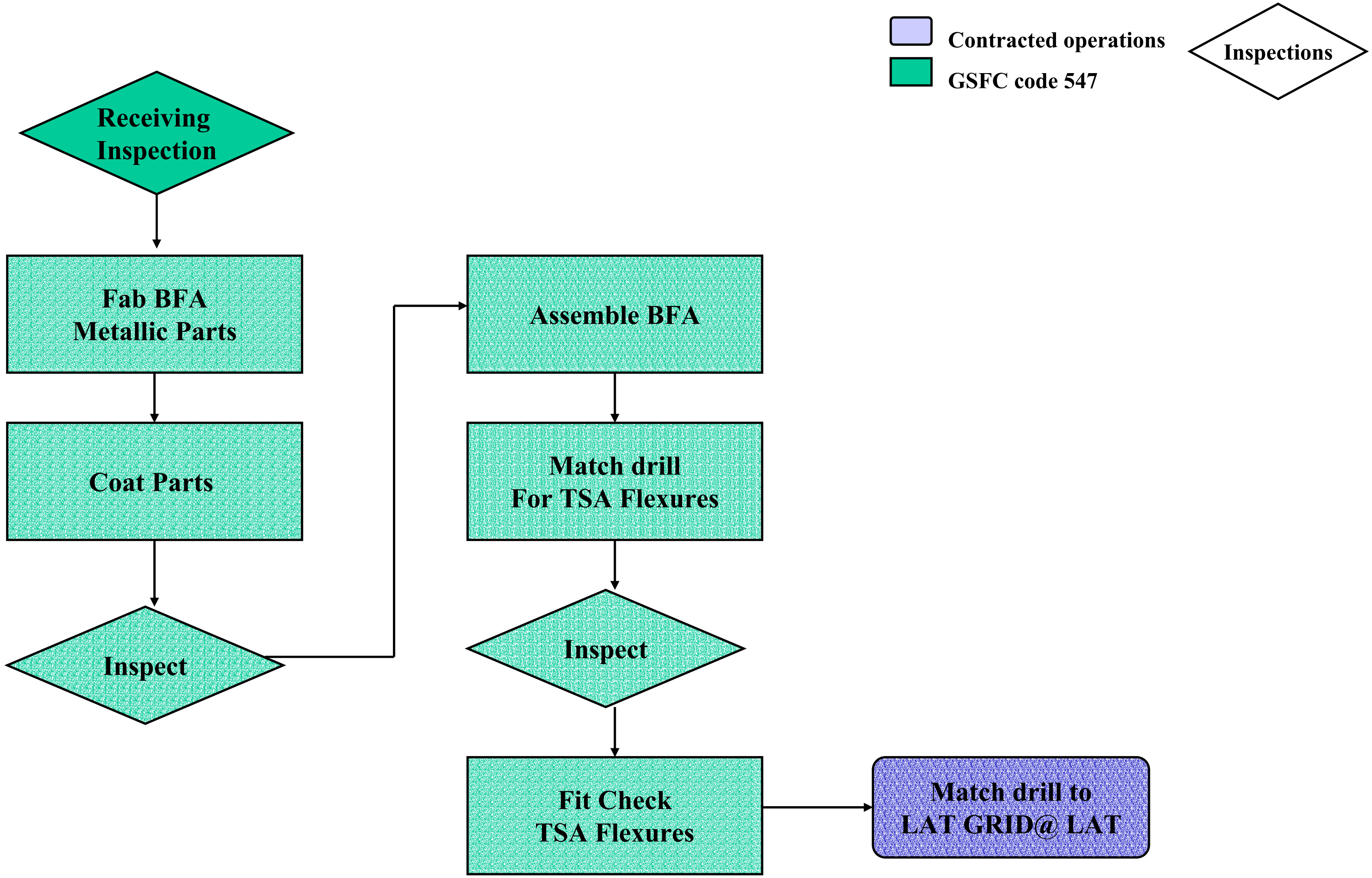
Components

- Tile Shell Assembly (TSA)
- Base Frame Assembly (BFA)

TSA Manufacturing Flow



BFA Manufacturing Flow

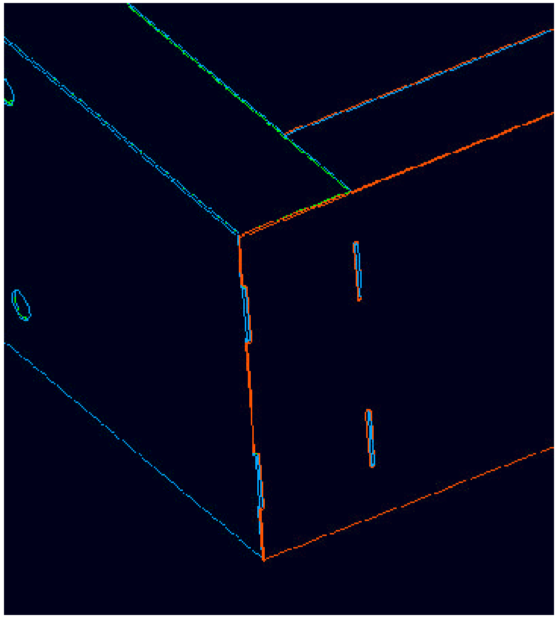


Tooling Methods

TSA panel alignment

Tab & slotted edge profiles to index panels to one another.

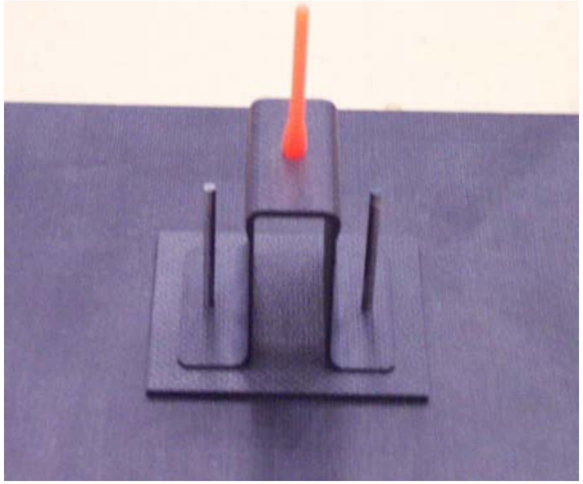
Surface plates & angle blocks

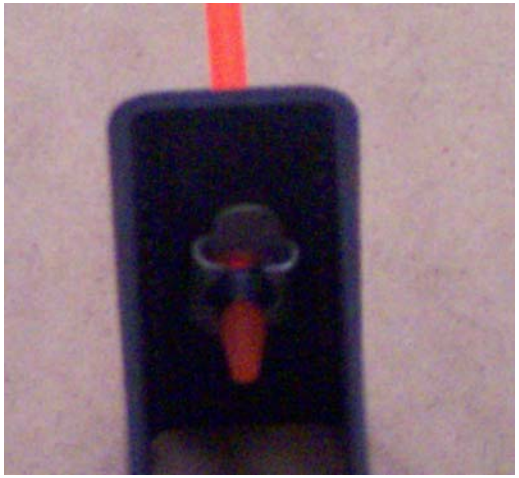


Tooling Methods

Tile flexure location

- .093” dia. Pins used to locate through flexure, doubler, and face sheet
- Pin locations drilled in outer face sheet used to locate flexure & doubler
- Click Bond alignment tools used for nut-plate





GSFC Composite Manufacturing Facilities

- Autoclave (3’dia. X 5’ deep)
- Blue M oven
- Lay-up room (20’ X 32’)
- High bay assembly area (36’ X 44” x 24’ high)
- Thermwood router
    - 20K rpm spindle
    - Vacuum bed

Materials

Shell Assembly		
Component	Material	Vendor
Shell Panel - Facesheets	M46J/EX-1522 Unidirectional Prepreg	Bryte Technologies
Shell Panels	Al. Honeycomb core	Alcor
Shell Panels	FM 73 Film Adhesive (.045 psf)	Cytec-Fiberite
Tile Flexures Doublers	T300/EX-1522 Cloth Prepreg	Bryte Technologies
Corner Clips	EA9396 (Wet lay-up resin)	Dexter-Hysol
Corner Clips	Carbon Ribbon (corner braids)	TBD

BFA	
Component	Material
Rails	Aluminum
Corner Fittings	Aluminum
TSA Flexures	Ti6-Al4V
Fasteners	As required, per S-313-100 “GSFC Fastener Integrity Requirements”

QA Inspections

- NDI Composite face sheets
- Ultrasonically inspect panel blanks
- Flat Wise Tension of sandwich panels (5 samples)
- Hardness witness for all adhesive mixes
- Tap Tests
- NDI of tile flexure bondlines
- Dimensional as required

Process Documentation

- **<u>SPECIFIC ACD MANUFCTURING</u>**

- **ACD SHELL PANEL SPECIFICATION (Preliminary)**
- **SHELL ASSEMBLY PROCEDURE (Preliminary)**
- **TILE FLEXURE LAY-UP PROCEDURE (Preliminary)**

- **<u>GENERAL GSFC MANUFACTURING</u>**

- **547-PG-5100.1.1 OUTSOURCING FOR FABRICATION SERVICES**
- **547-PG-5330.1.1 FASTENER INSPECTION TEST PLAN**
- **547-PG-5330.1.2 MECHANICAL INSPECTION**
- **547-PG-8072.1.1 MANUFACTURING PROCESS**
- **547-PG-8730.1.1 GUIDELINES FOR USING INSPECTION, MEASUREMENT, & TEST EQUIPMENT IN MECHANICAL H/W MFG FACILITIES**
- **547-PG-8730.1.2 CALIBRATION AND METROLOGY IMPLEMENTATION**
- **548-WI-8072.1.13 : QUALITY PLAN IN THE ELECTROPLATING LABORATORY**
- **548-WI-8072.1.15 : PROCESS CONTROL FOR HEAT TREATING**

Process Documentation

- **GSFC COMPOSITE PRODUCT MANUFACTURING**

- 547-WI-8072.2.1.7 : PREPARATION AND APPLICATION OF TWO PART EPOXY PASTE ADHESIVE
- 547-WI- 8072. 2.1.8 : AUTOCLAVE OPERATION
- 547-WI- 8072. 2.1.10 : SURFACE PREPARATION OF ALUMINUM AND TITANIUM ALLOYS FOR ADHESIVE BONDING
- 547-WI- 8072. 2.1.11 : SURFACE PREPARATION OF POLYMER MATRIX COMPOSITES FOR ADHESIVE BONDING
- 548-WI-5100.1.1 : PURCHASING FIBER-REINFORCED PREPREG MATERIAL FOR SPACE APPLICATIONS
- 548-WI-8072.1.2 : PROCESS CONTROL LOG FOR LAMINATES
- 548-WI-8072.1.4 : PROCESS CONTROL FOR ELECTROPLATING
- 548-WI-8072.1.5 : PROCESS CONTROL DOCUMENTATION FOR BONDED ASSEMBLIES
- 548-WI-8072.1.7 : RECEIVING AND FREEZER STORAGE OF PREPREGS AND FILM ADHESIVES
- 548-WI-8072.1.8 : PREPREG INSPECTION AND DATABASE RECORDING
- 548-WI-8072.1.10 : THE MIX RECORD, A PROCESS RECORD FORM FOR PASTE ADHESIVES

ACD CDR
Mechanical Sub-System - Summary

- Met the challenge of mounting largely different CTE materials together.
- Identified designs are not yet complete and plans of action to complete designs
- Identified Issues that need to be addressed by the Mechanical team Team members, and our plans of action.

ACD Element	Progress to Date	Status
Shell Assembly	Designed, analyzed, partially tested	Shell Assembly will be ready for flight build following fixing shell temperatures and completing insert tests.
•Tile Flexures		
–Nominal Flexures	•Designed, analyzed, tested	•Ready for Flight Build
–Bottom Flexures	•Designed, analyzed	•Bottom tile flexure will be ready for flight build following completion of validation tests.
–Angled Tile Mounts	•Designed	•Angled flexures ready for flight build following analyses and testing.
Base Frame Assembly	Designed, analyzed	BFA will be ready for flight build following engineering model fabrication and fit tests and signature of IDD.
Thermal system	Designed, analyzed	Ready for flight build